

Instituto Federal de Educação, Ciência e Tecnologia de Santa Catarina

Departamento Acadêmico de Eletrônica

Eletrônica de Potência



Modulação PWM Senoidal

Prof. Clovis Antonio Petry.

Florianópolis, outubro de 2025.

Eletrônica de Potência

O material do curso está disponível em:

1. Moodle para os alunos matriculados na disciplina.
2. Página do professor.
3. Canal no youtube do professor.



<https://moodle.ifsc.edu.br>

ProfessorPetry
Conhecimento para uma vida plena

PRINCIPAL PROJÉTOS PUBLICAÇÕES CONTATO



Bem vindo ao Website pessoal de Clovis Antonio Petry

O objetivo desta página é a divulgação de informações sobre eletrônica, em especial eletrônica de potência. Todos os materiais disponibilizados podem ser livremente utilizados, desde que citados os autores. As disciplinas do semestre corrente podem ser acessadas clicando na imagem da esquerda abaixo. Material didático pode ser encontrado clicando na imagem da direita abaixo.



Eventos

Outubro, 2020
SNCT 2020
Semana Nacional de Ciência e Tecnologia 2020, Florianópolis, SC.
[Acesse...](#)

Setembro, 2020
COBENGE 2020
XLVIII Congresso Brasileiro de Educação em Engenharia (COBENGE) e III Simpósio Internacional de Educação em Engenharia da ABENGE, Bento Gonçalves, RS. [Acesse...](#)

www.ProfessorPetry.com.br



<https://www.youtube.com>

Agenda

Introdução aos conversores cc-ca:

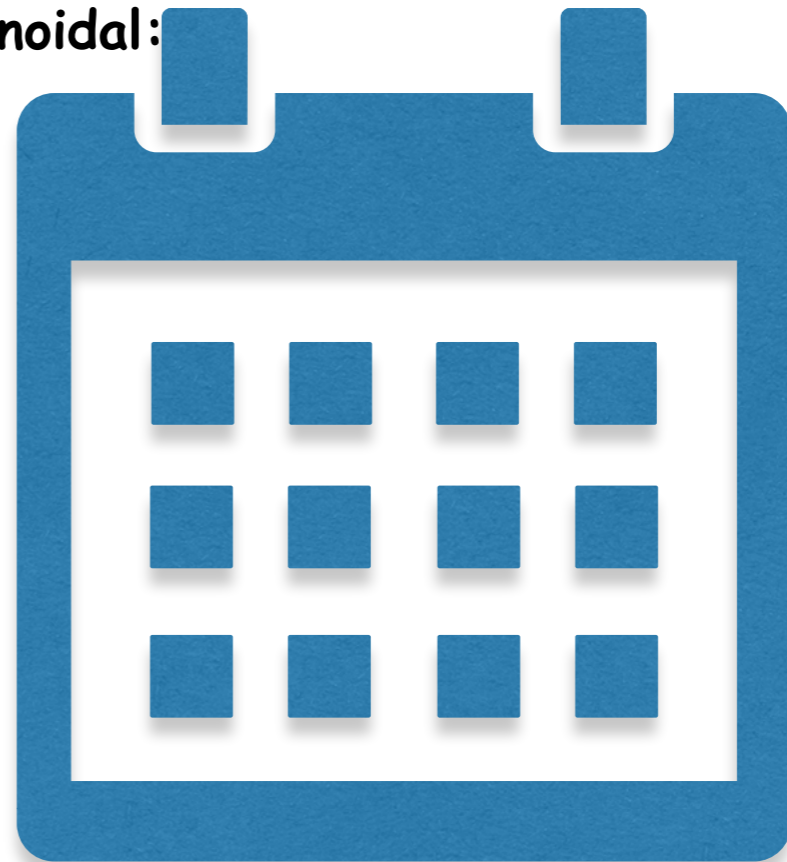
- Quadrantes de operação.

Conversores cc-cc: modulação por largura de pulsos:

- Princípio geral;
- Circuitos analógicos;
- Circuitos dedicados.

Conversores cc-ca: modulação por largura de pulsos senoidal:

- Simulação de conversores Buck;
- Simulação com modulação PWM senoidal.

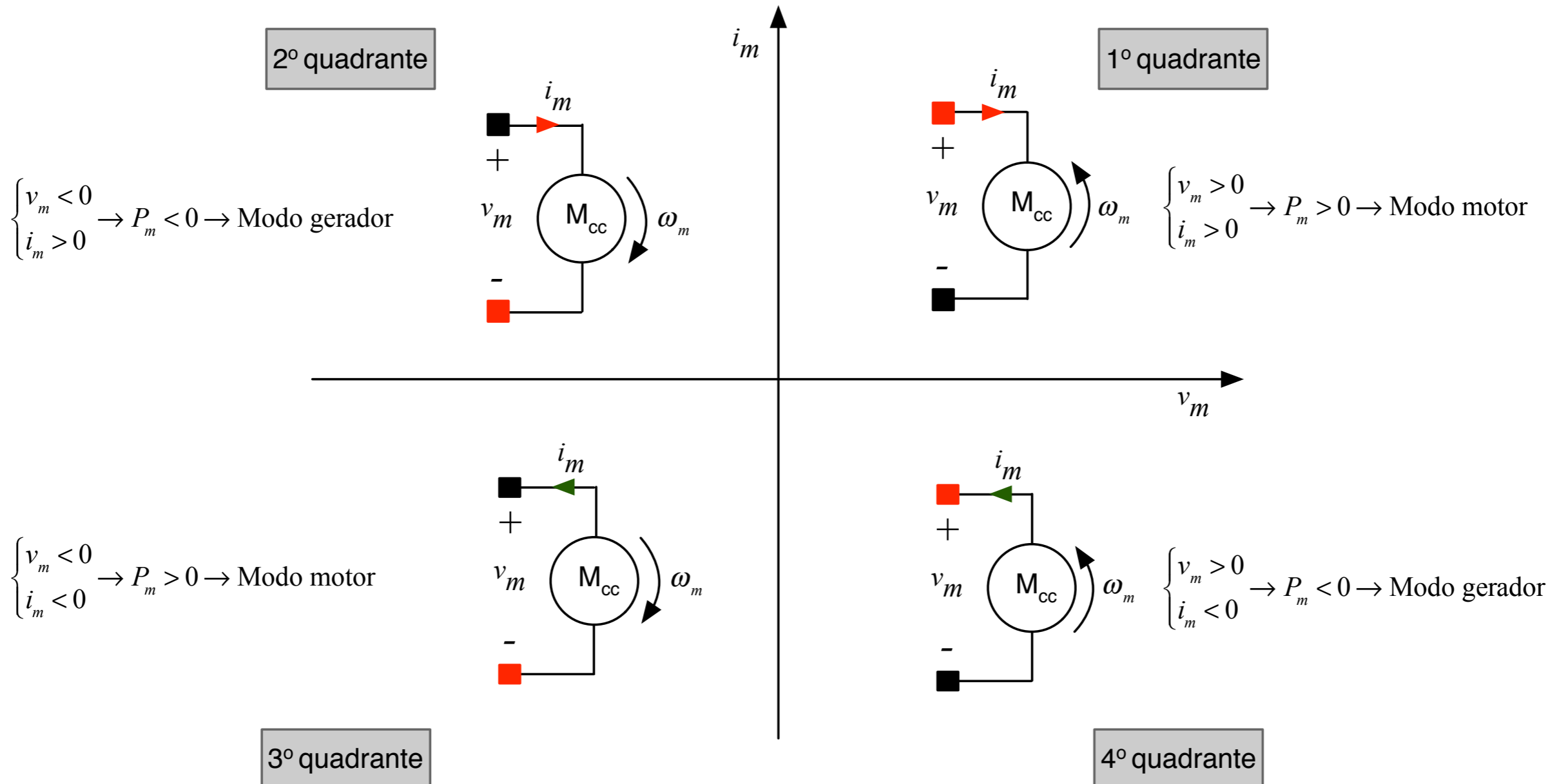


Motivação

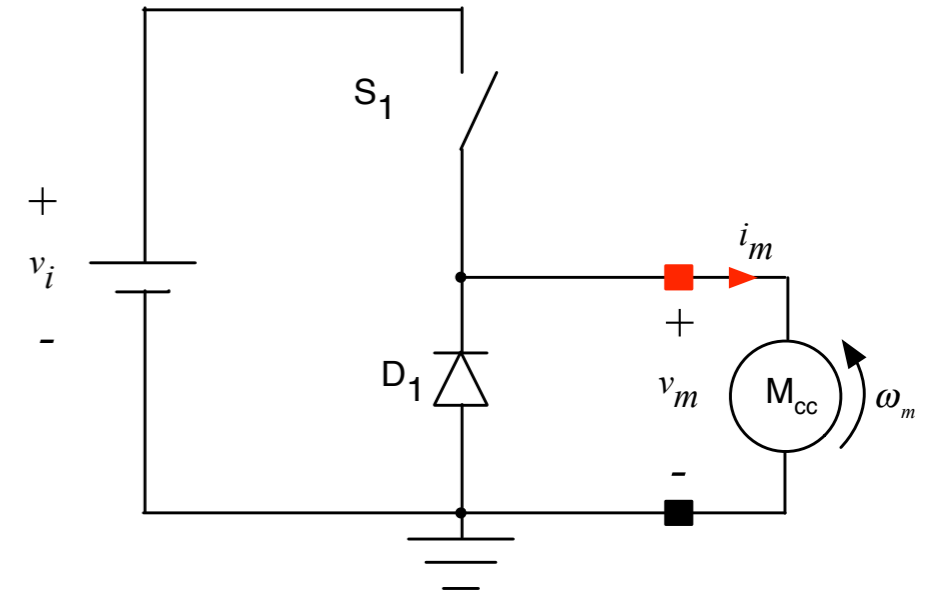
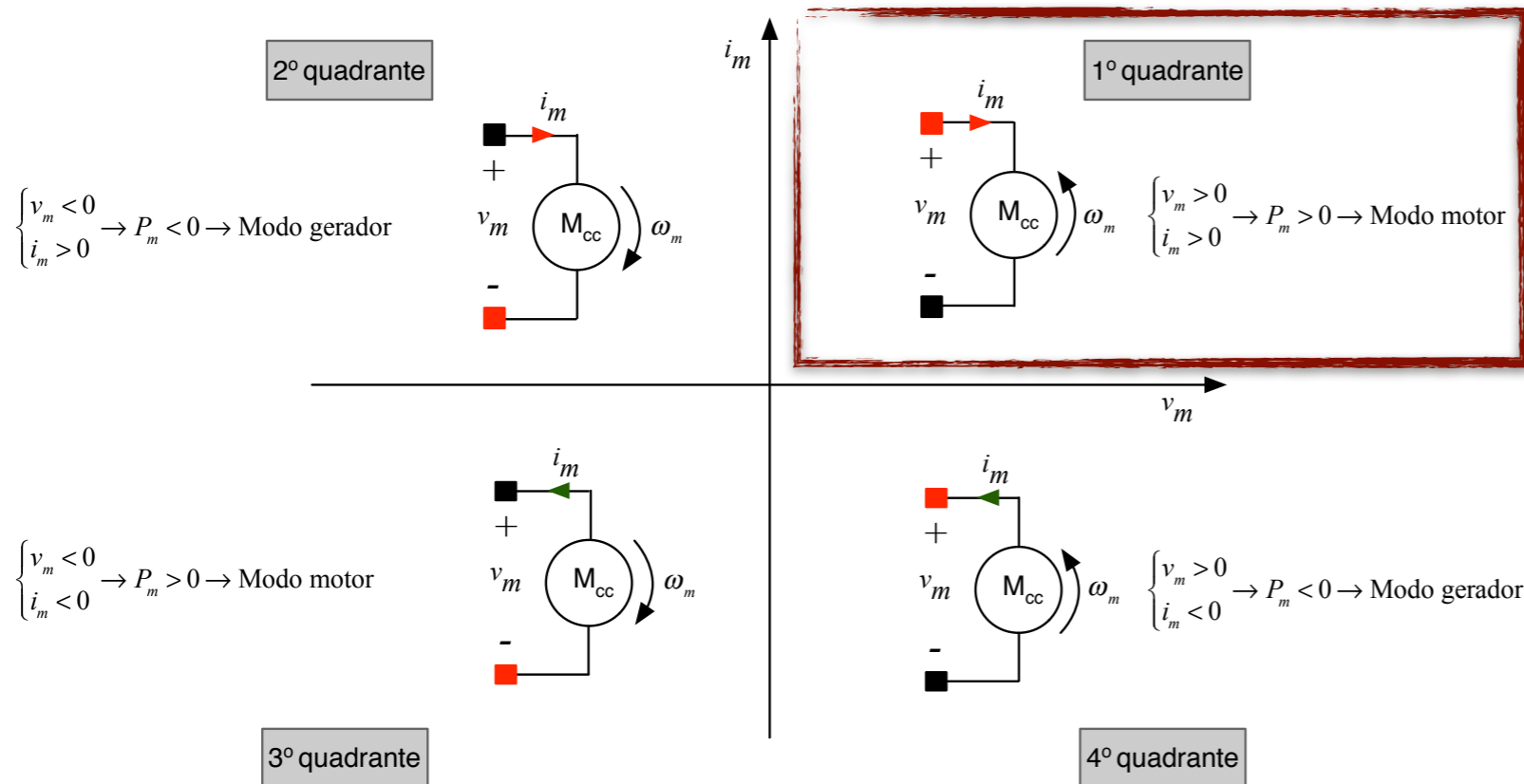
Os conversores cc-ca tem ampla utilização na indústria, por exemplo no acionamento de motores.



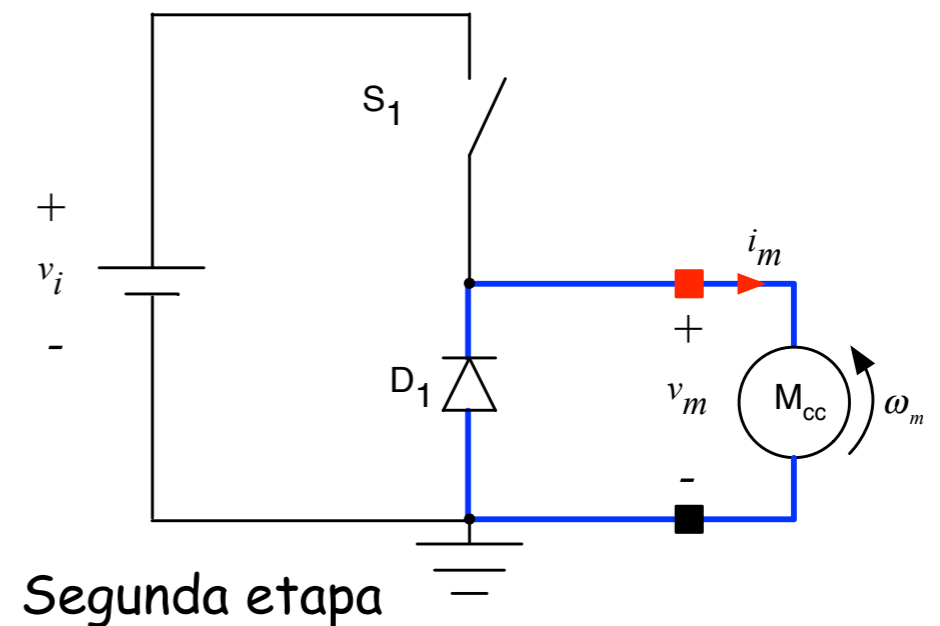
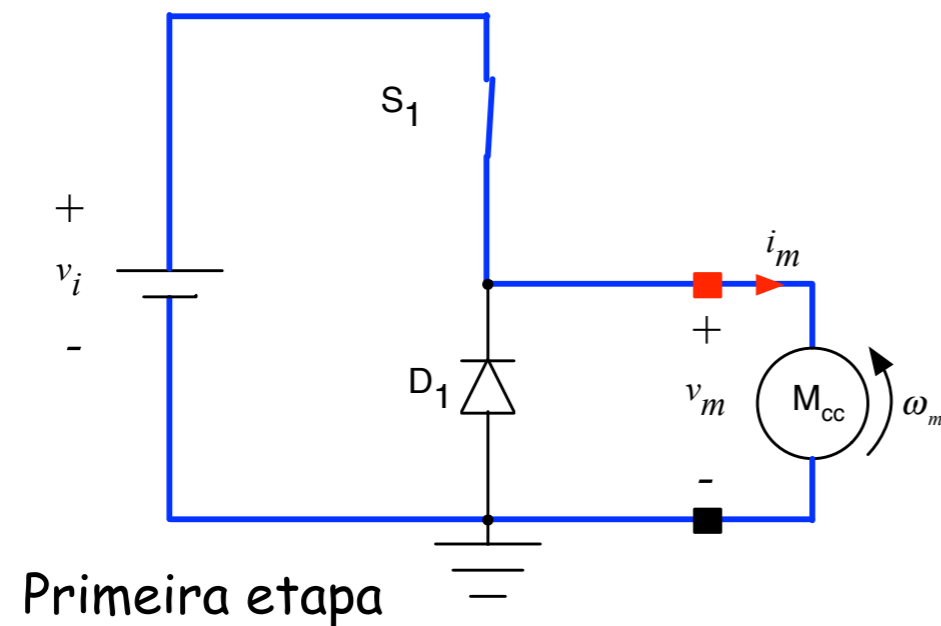
Quadrantes de Operação



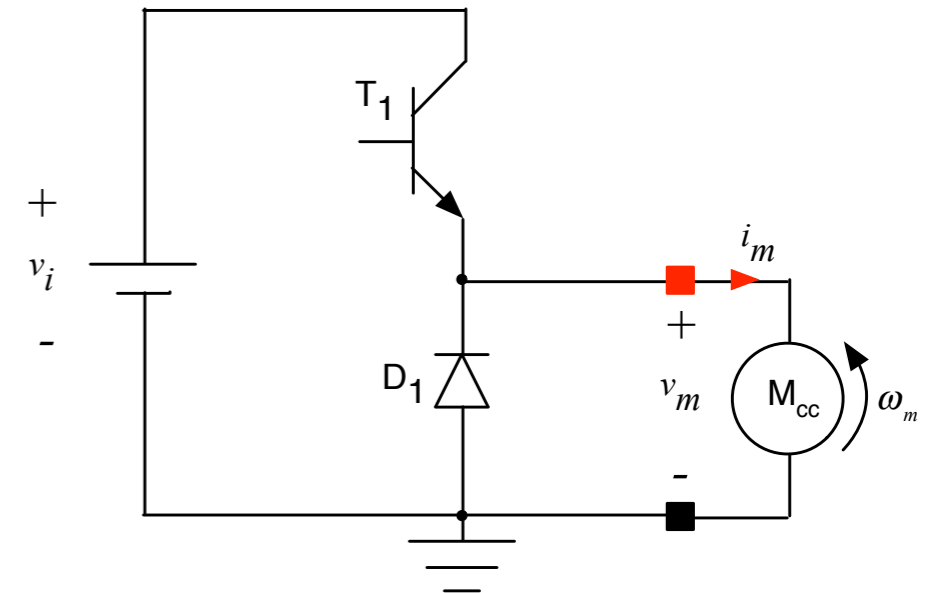
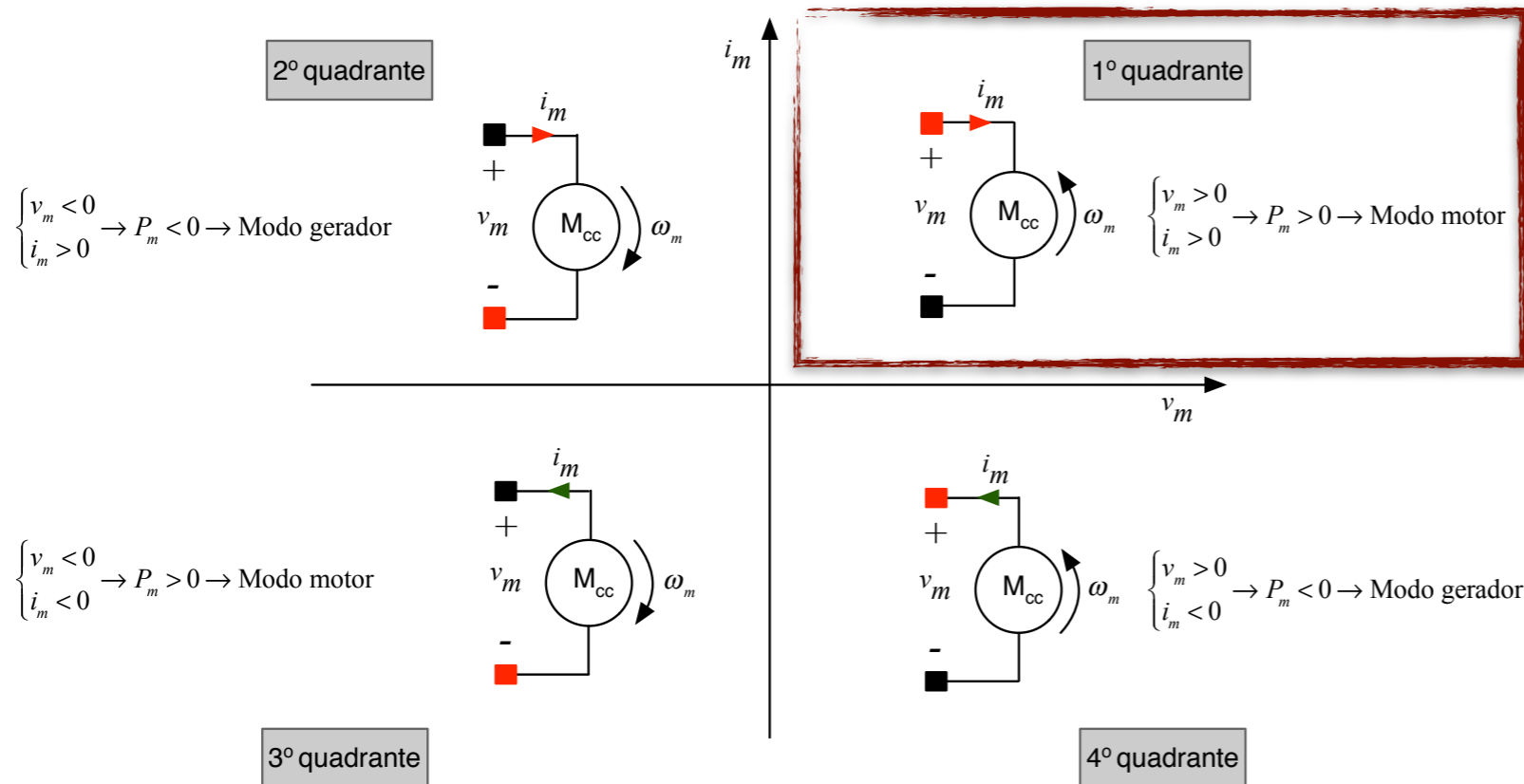
Quadrantes de Operação



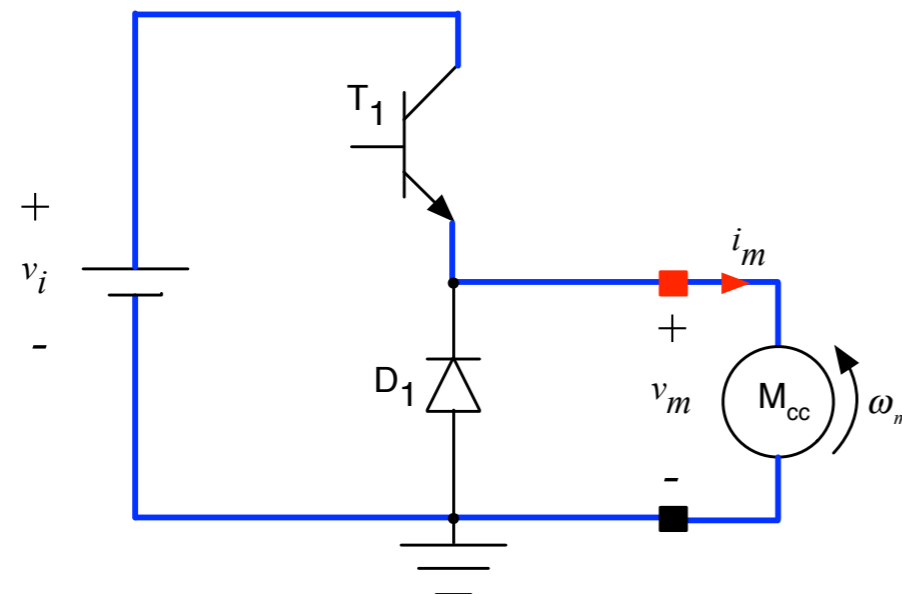
Conversor simples com chave



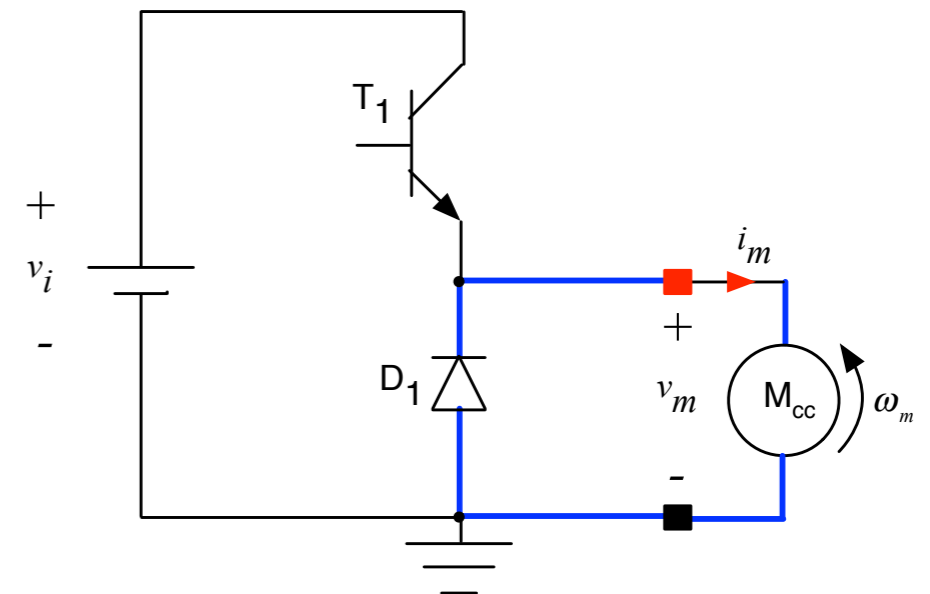
Quadrantes de Operação



Conversor simples com transistor

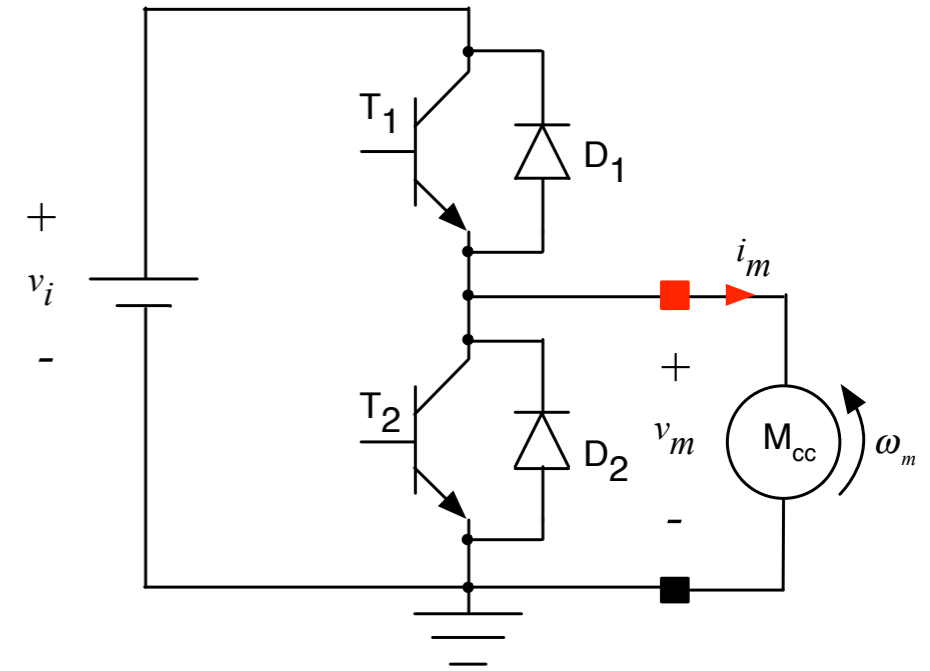
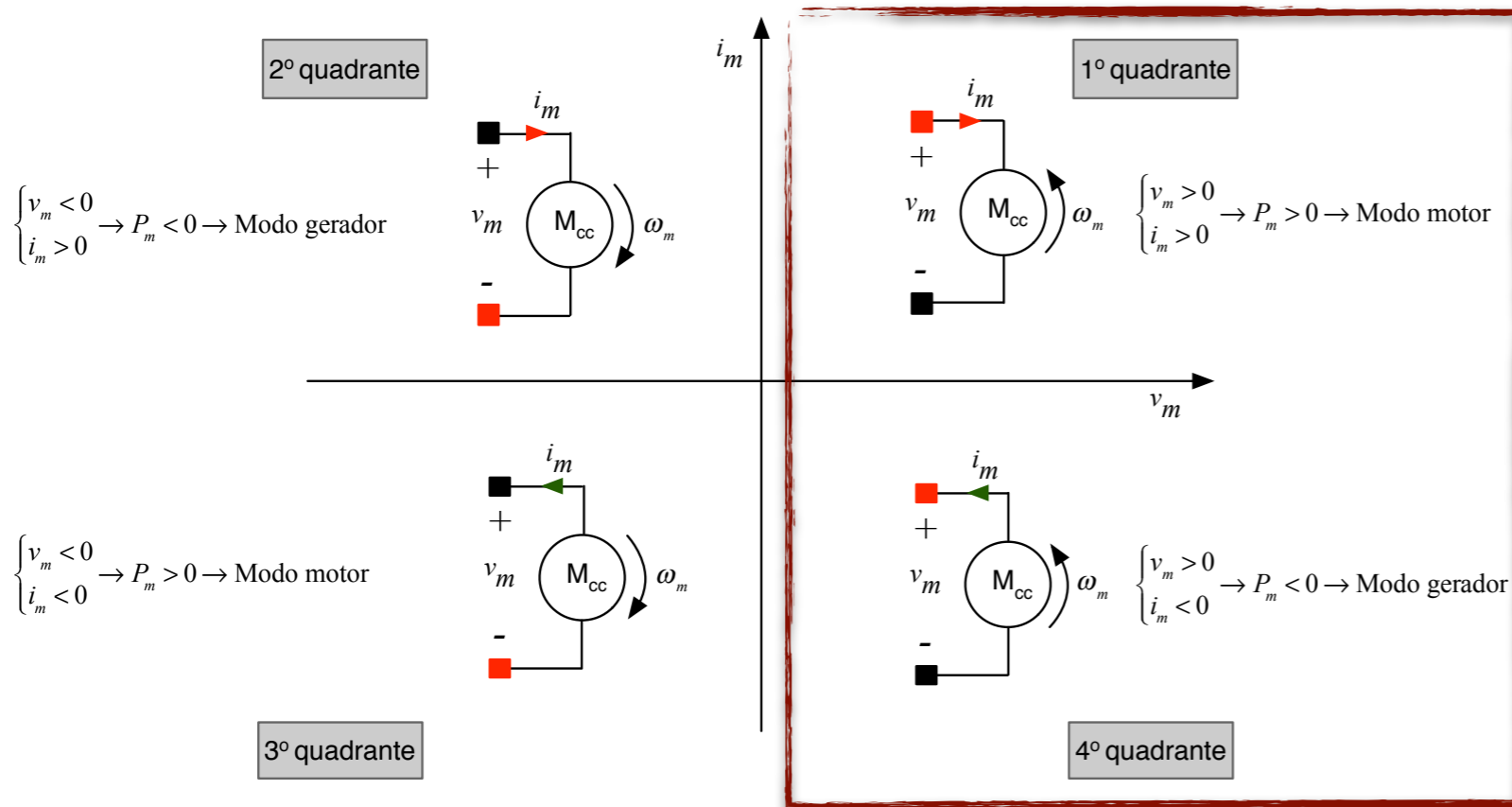


Primeira etapa



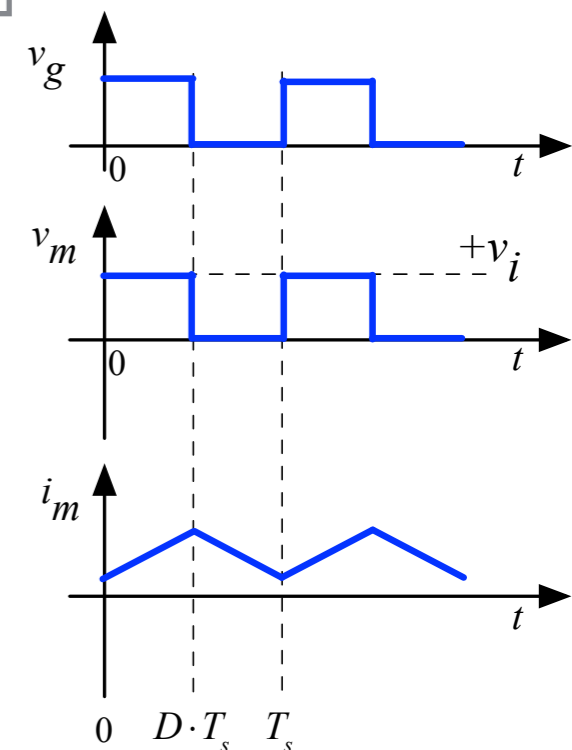
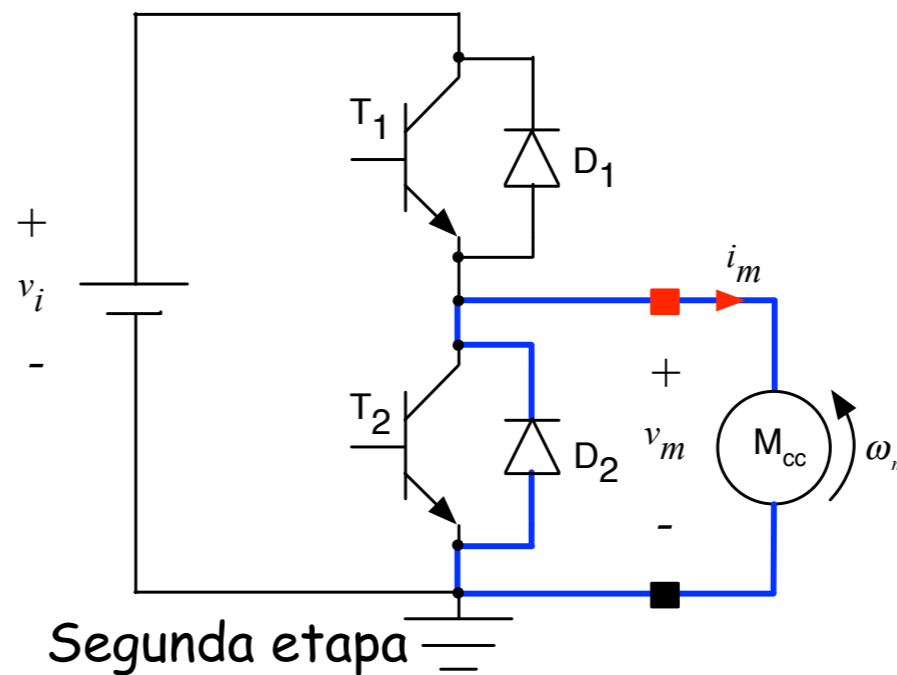
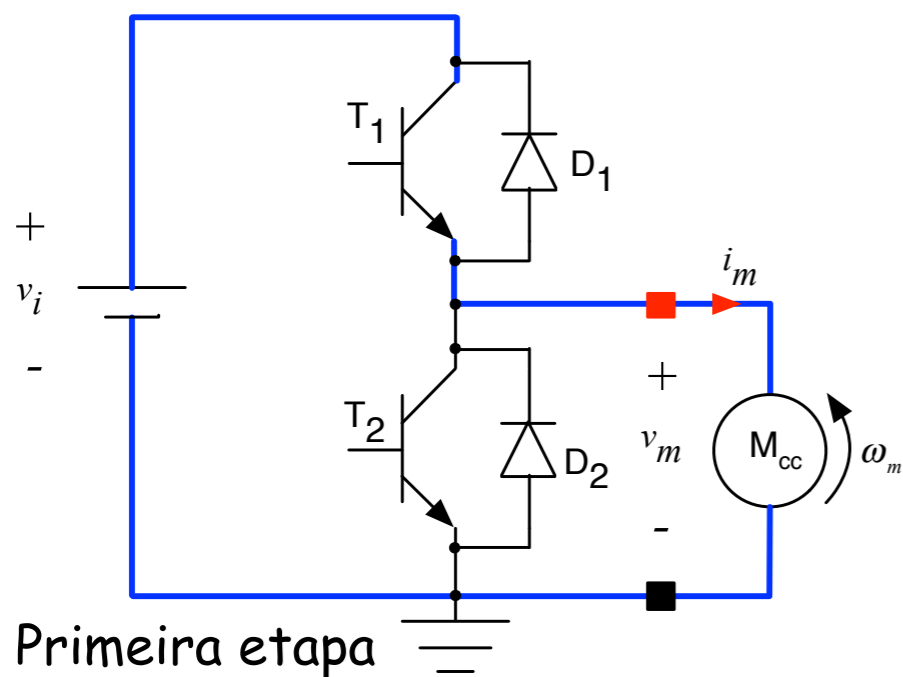
Segunda etapa

Quadrantes de Operação

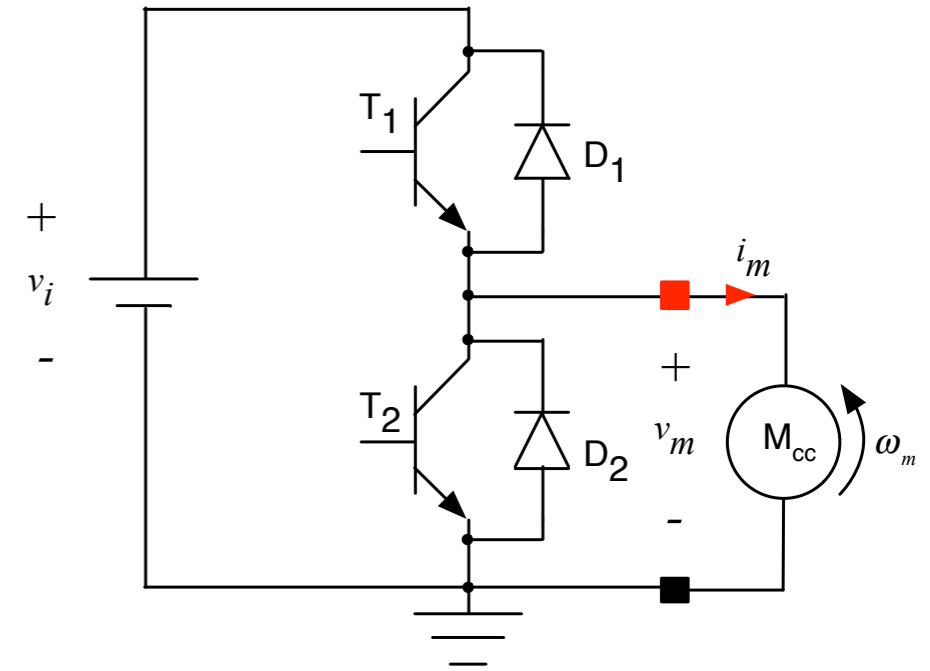
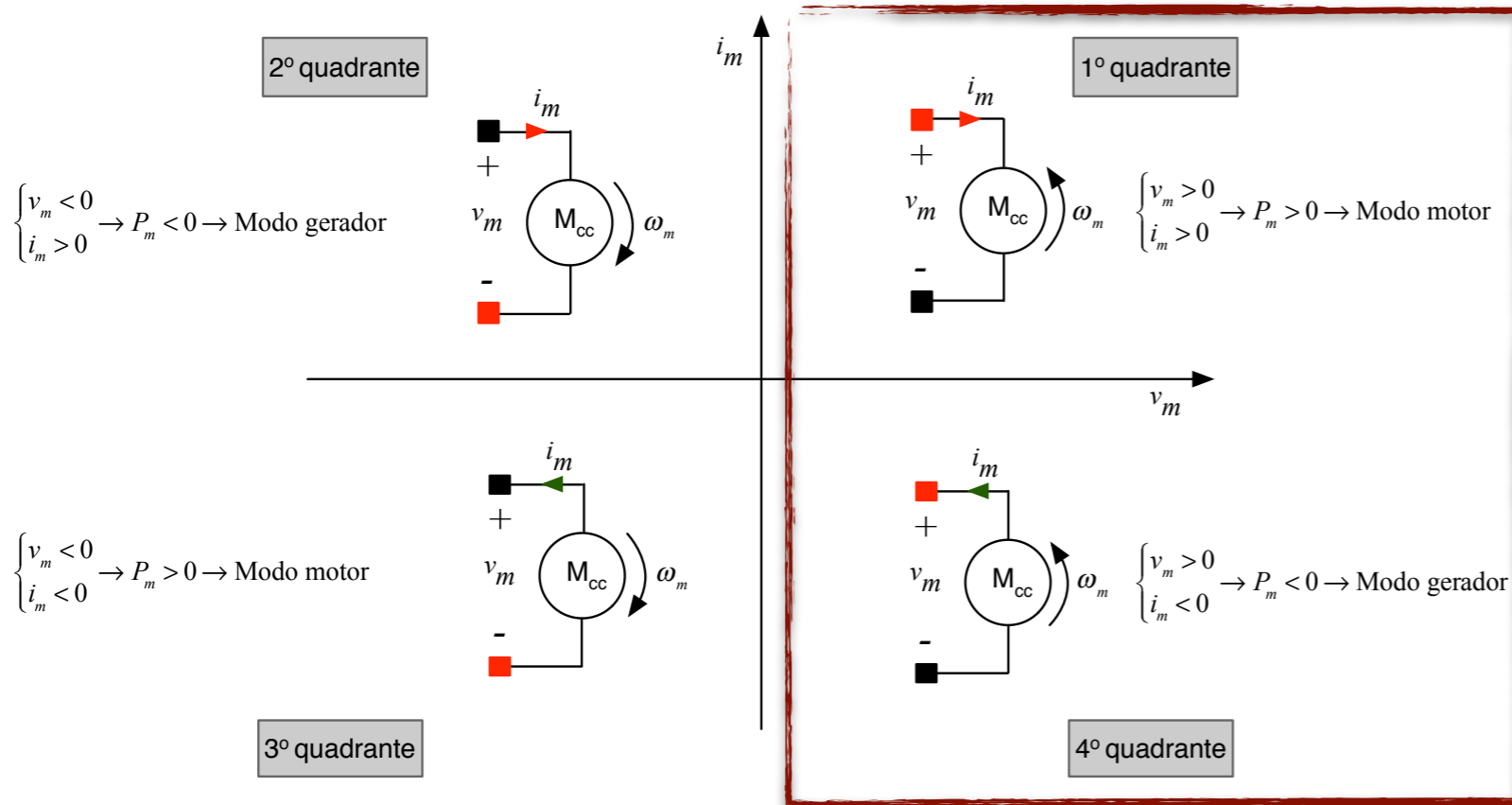


Conversor meia ponte

Modo motor

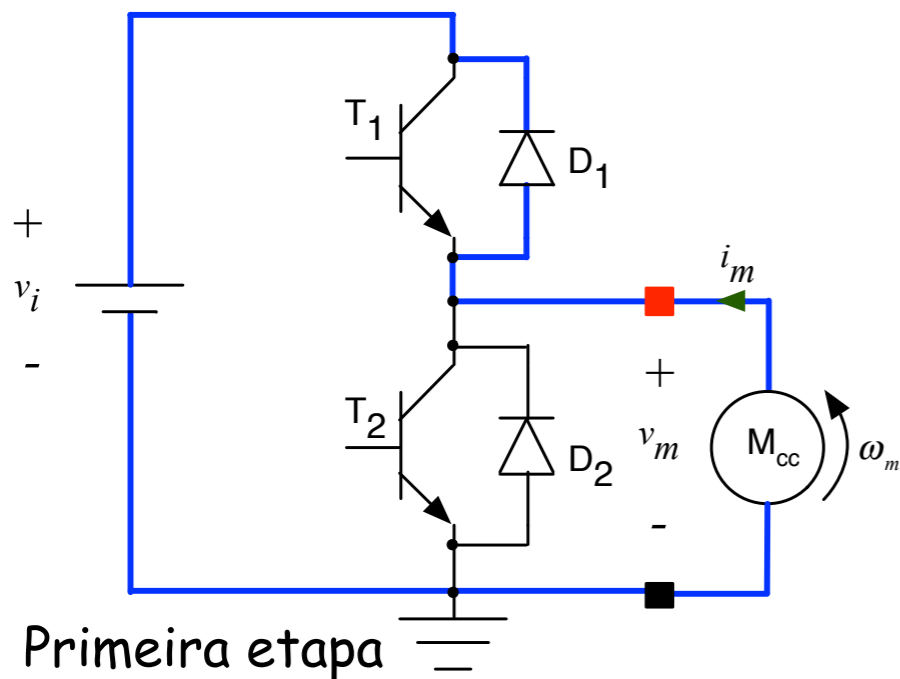


Quadrantes de Operação

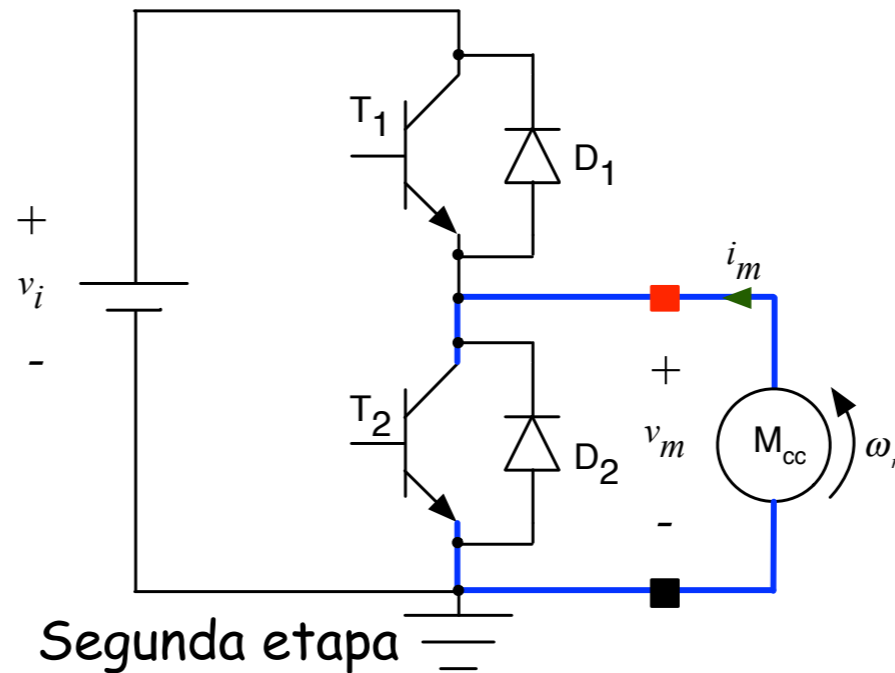


Conversor meia ponte

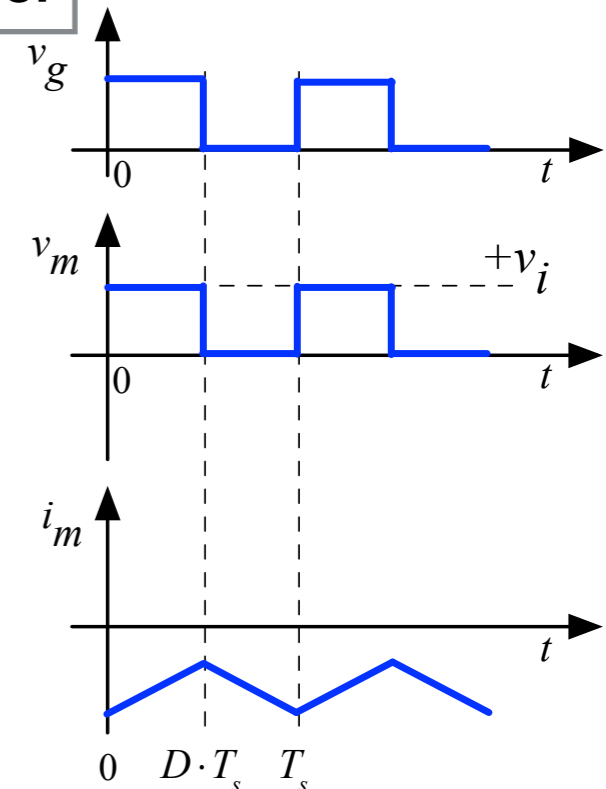
Modo gerador



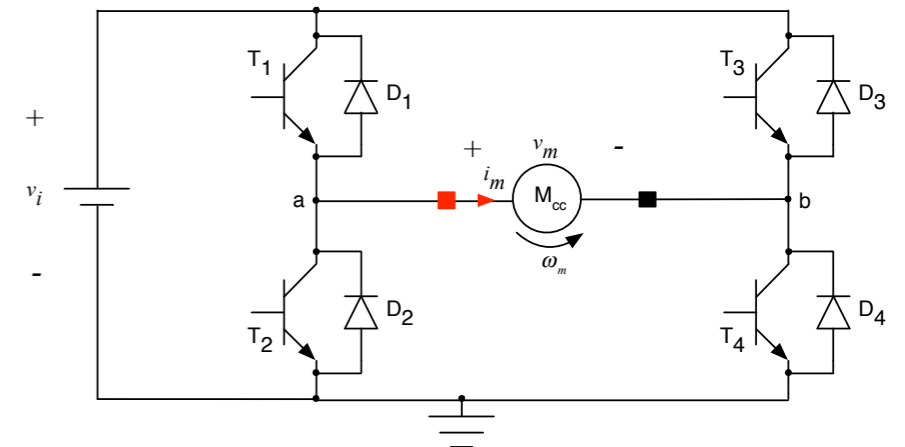
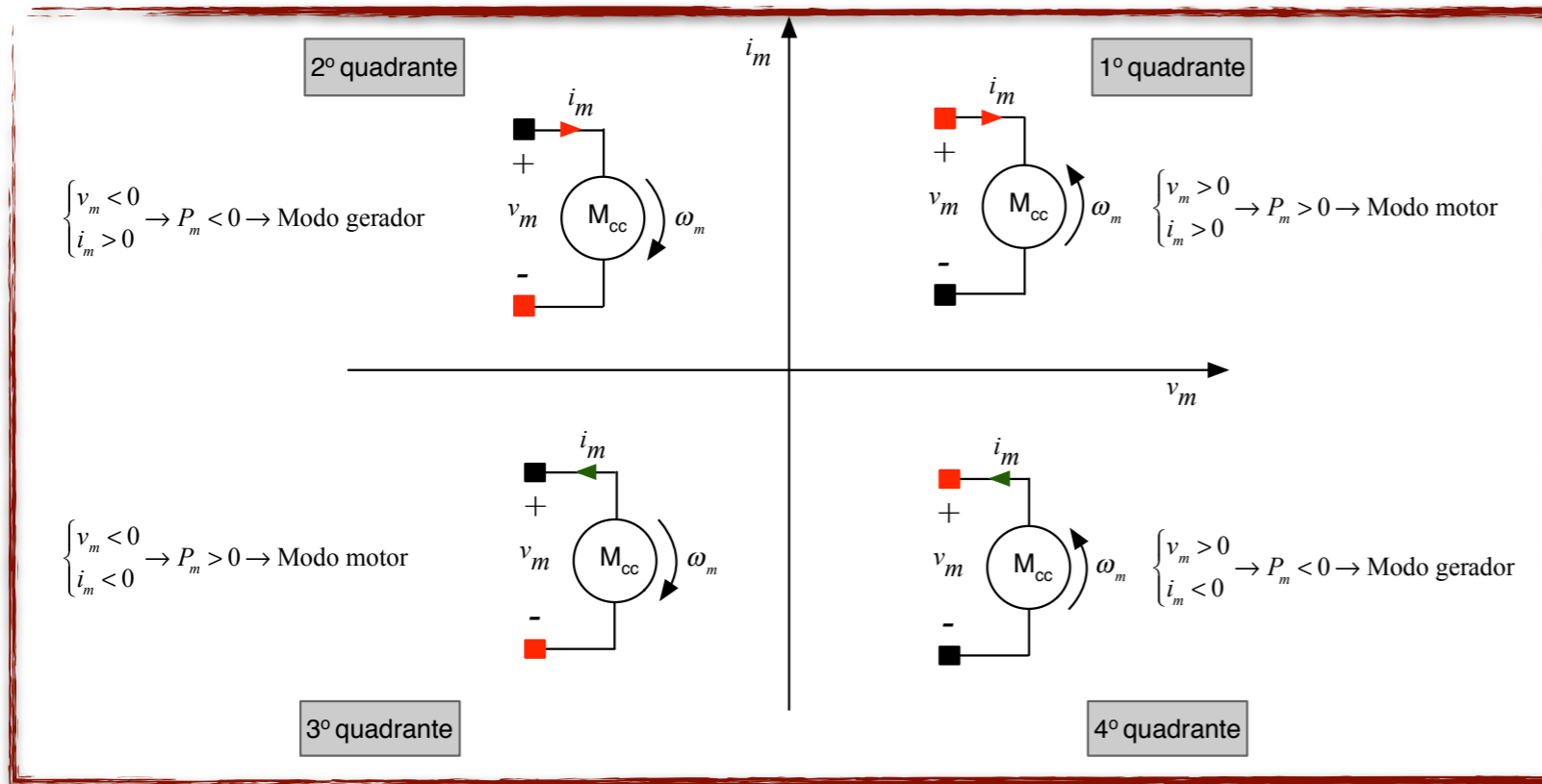
Primeira etapa



Segunda etapa

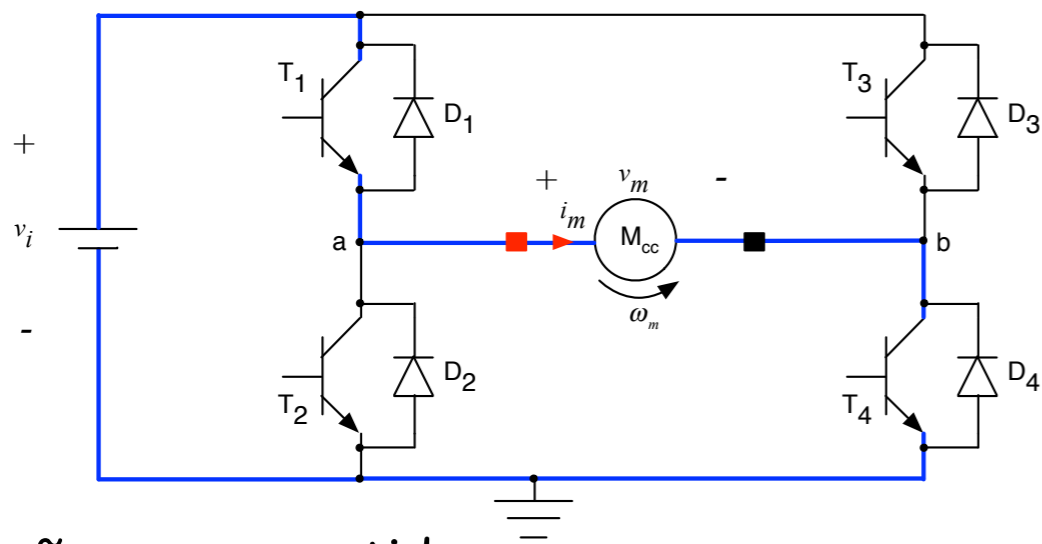


Quadrantes de Operação

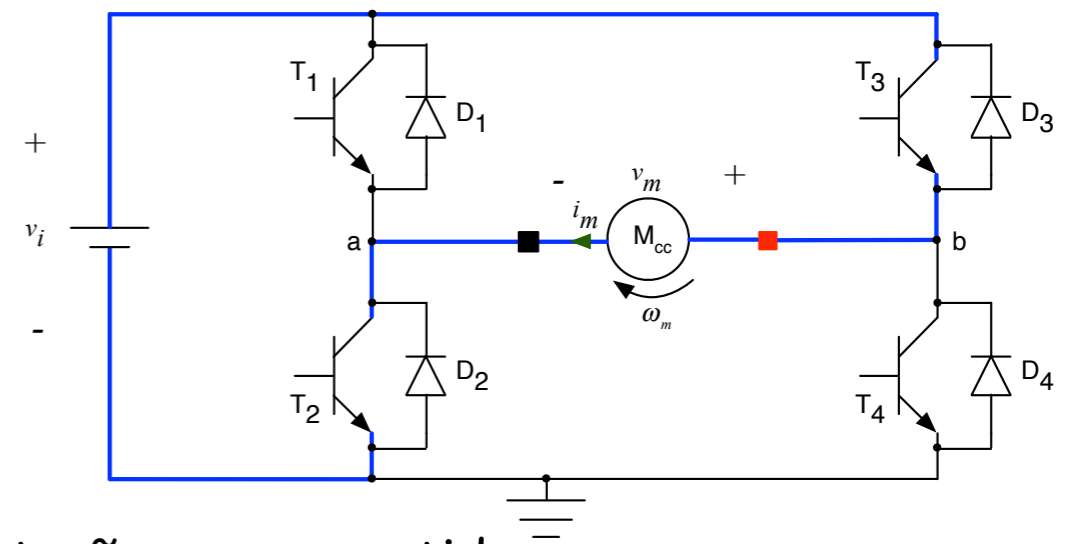


Conversor ponte completa

Modo motor

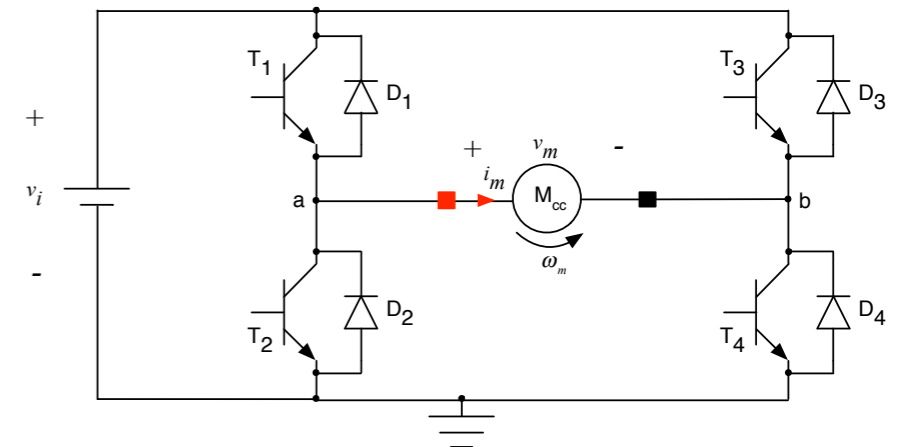
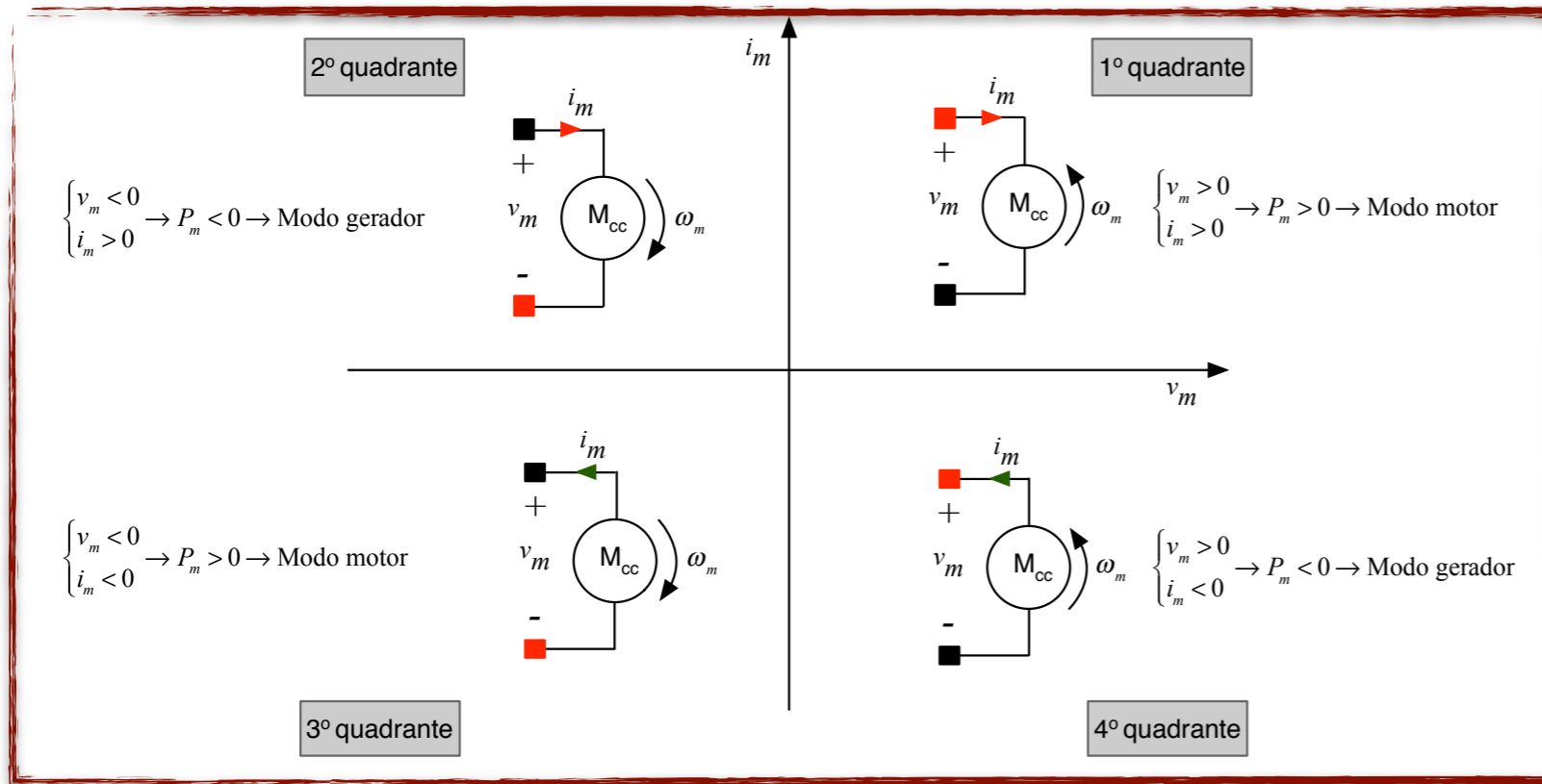


Rotação em um sentido



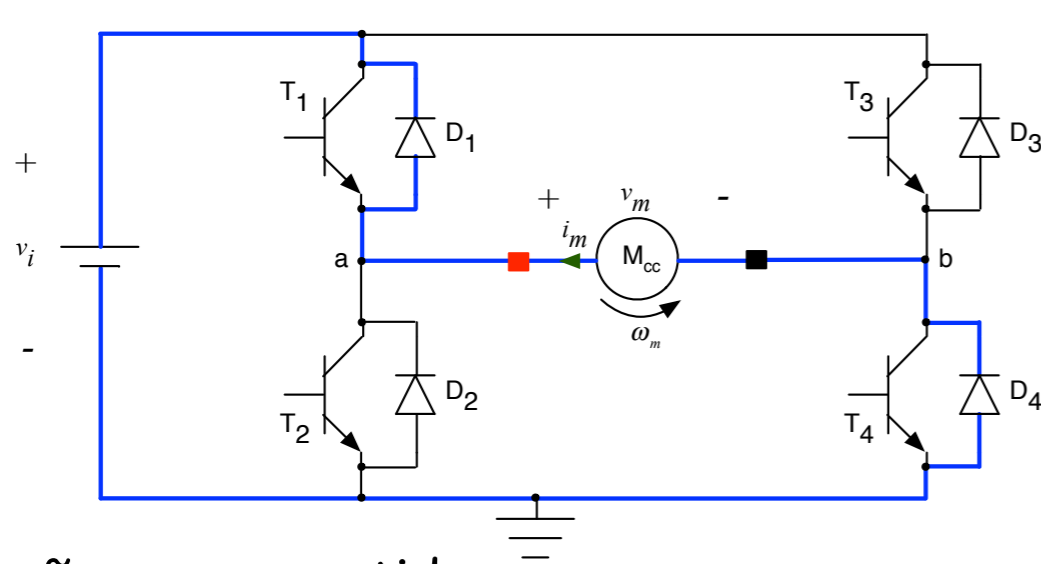
Rotação em um sentido

Quadrantes de Operação

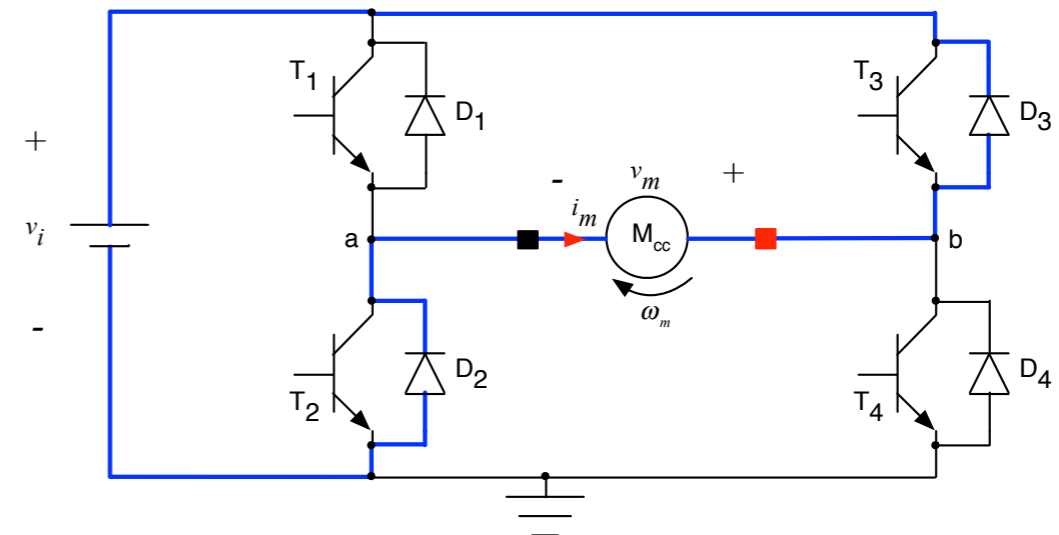


Conversor ponte completa

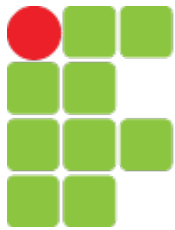
Modo gerador



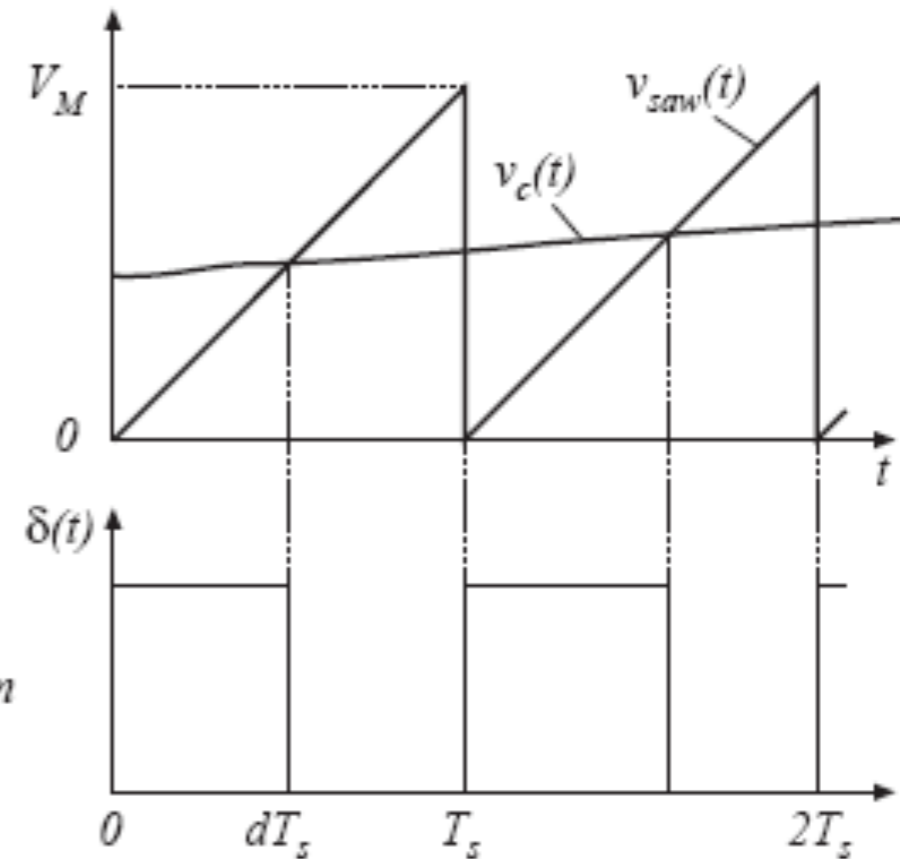
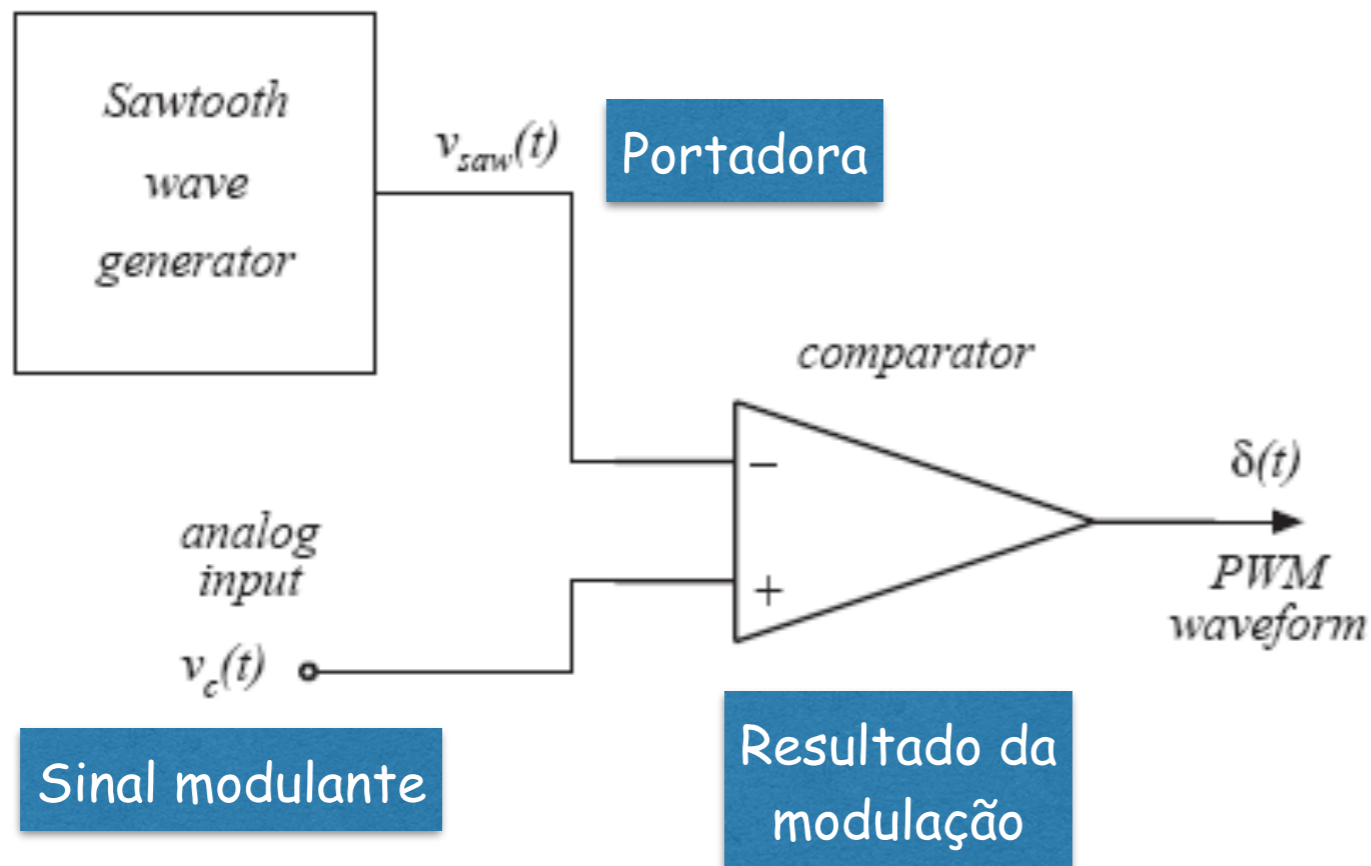
Rotação em um sentido



Rotação em um sentido

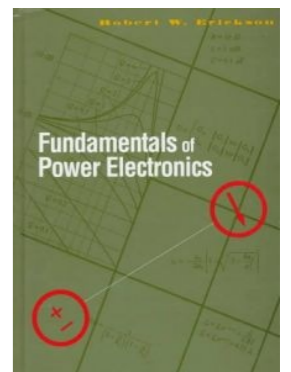


Modulação PWM



Considerações:

1. A portadora define a frequência de comutação;
2. O sinal modulante deve ser aproximadamente contínuo durante um período da portadora;
3. O sinal modulante define a fundamental da grandeza de saída do conversor.



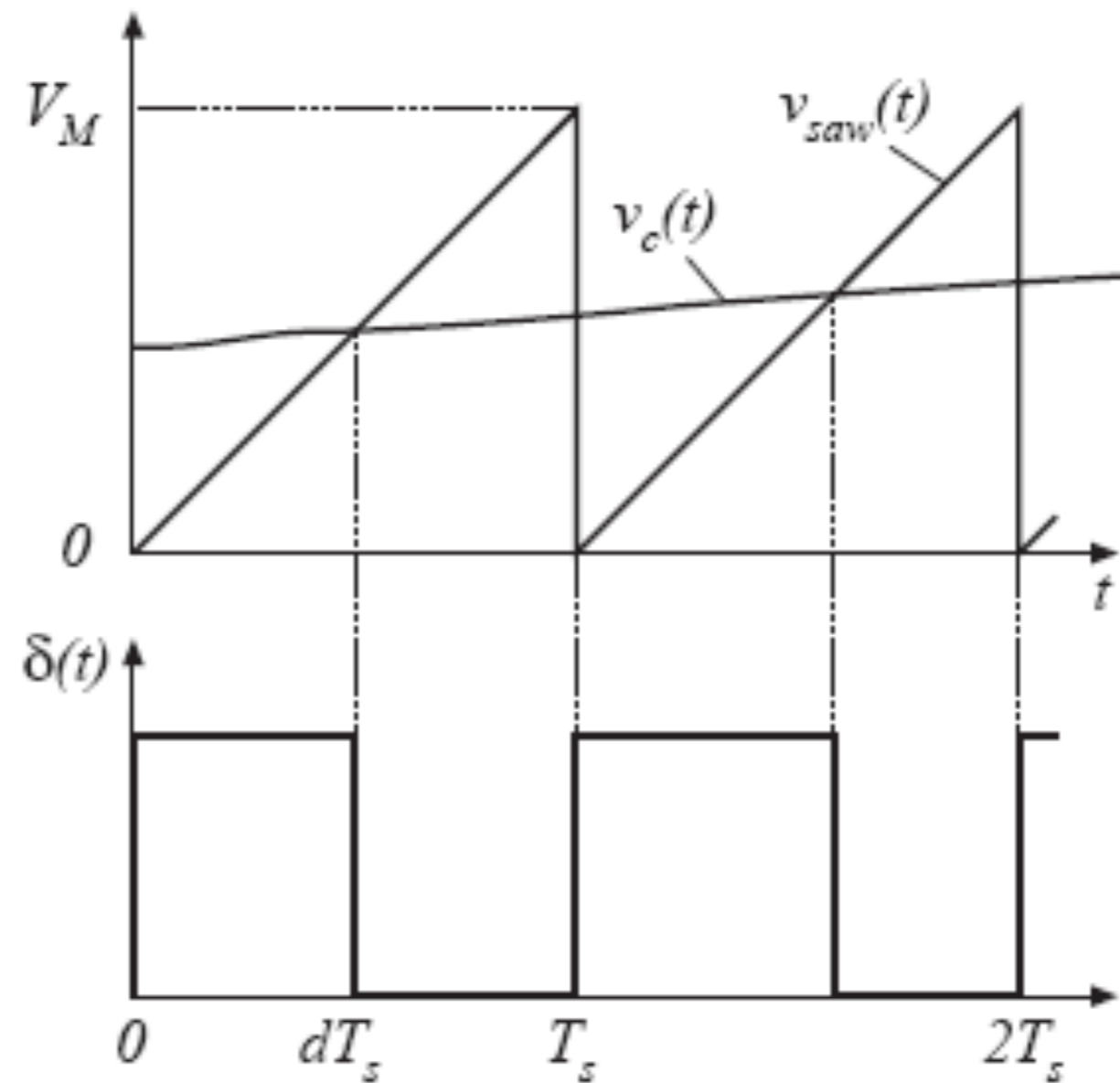
Modulação PWM

Considerando uma dente-de-serra linear:

$$d(t) = \frac{v_c(t)}{V_M}$$

Para:

$$0 \leq v_c(t) \leq V_M$$



Modulação PWM

Perturbando o sinal no tempo:

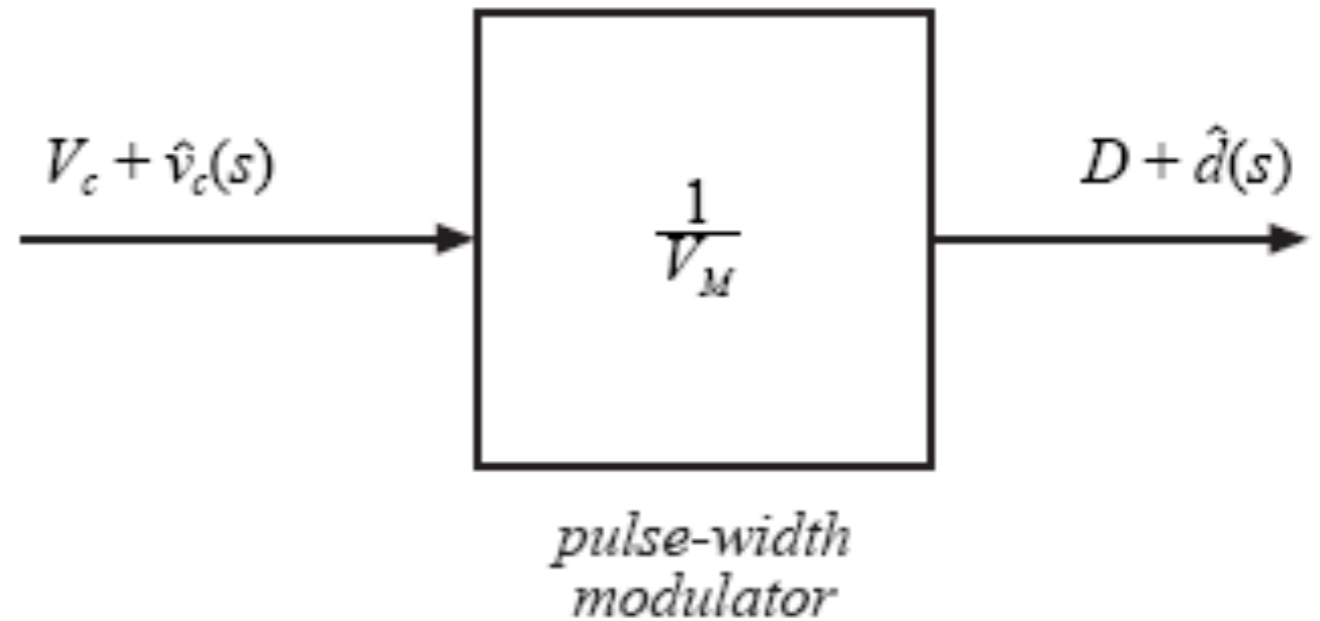
$$d(t) = D + \hat{d}(t)$$

$$v_c(t) = V_c + \hat{v}_c(t)$$

Resultado:

$$d(t) = \frac{v_c(t)}{V_M}$$

$$D + \hat{d}(t) = \frac{V_c + \hat{v}_c(t)}{V_M}$$

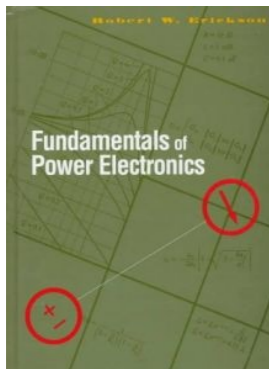


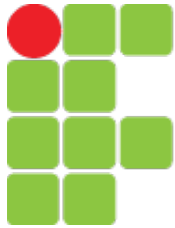
Relações CC:

$$D = \frac{V_c}{V_M}$$

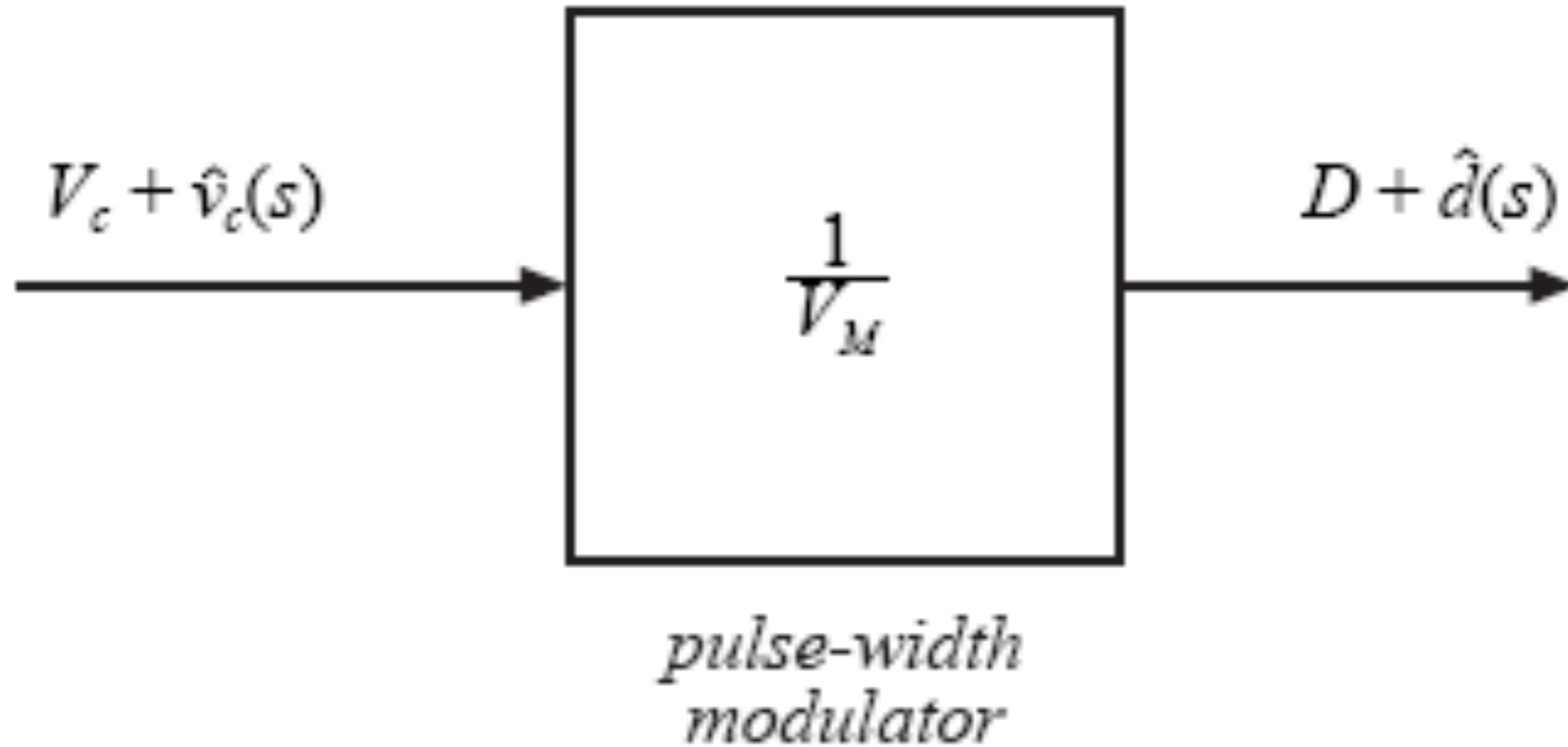
Relações CA:

$$\hat{d}(t) = \frac{\hat{v}_c(t)}{V_M}$$





Modulação PWM



$$D = \frac{V_c}{V_M}$$

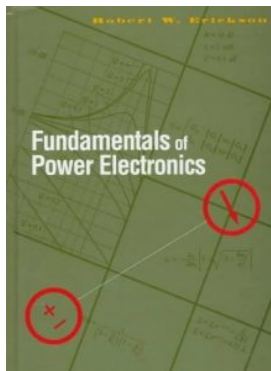
CC

$$\hat{d}(t) = \frac{\hat{v}_c(t)}{V_M}$$

No tempo

$$D(s) = \frac{V_c(s)}{V_M}$$

Na frequência

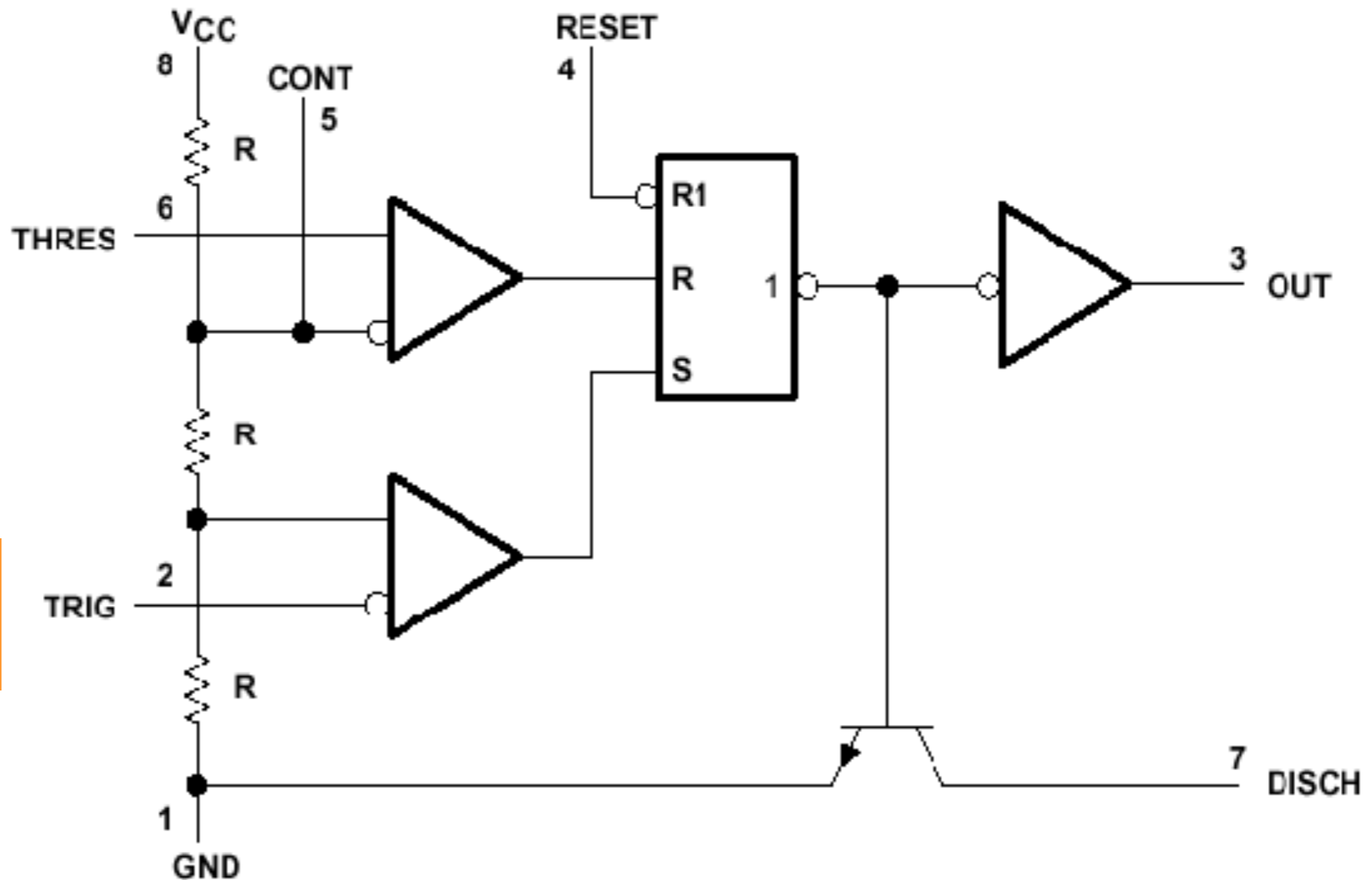


Circuitos Analógicos

Modulador PWM usando temporizador 555:

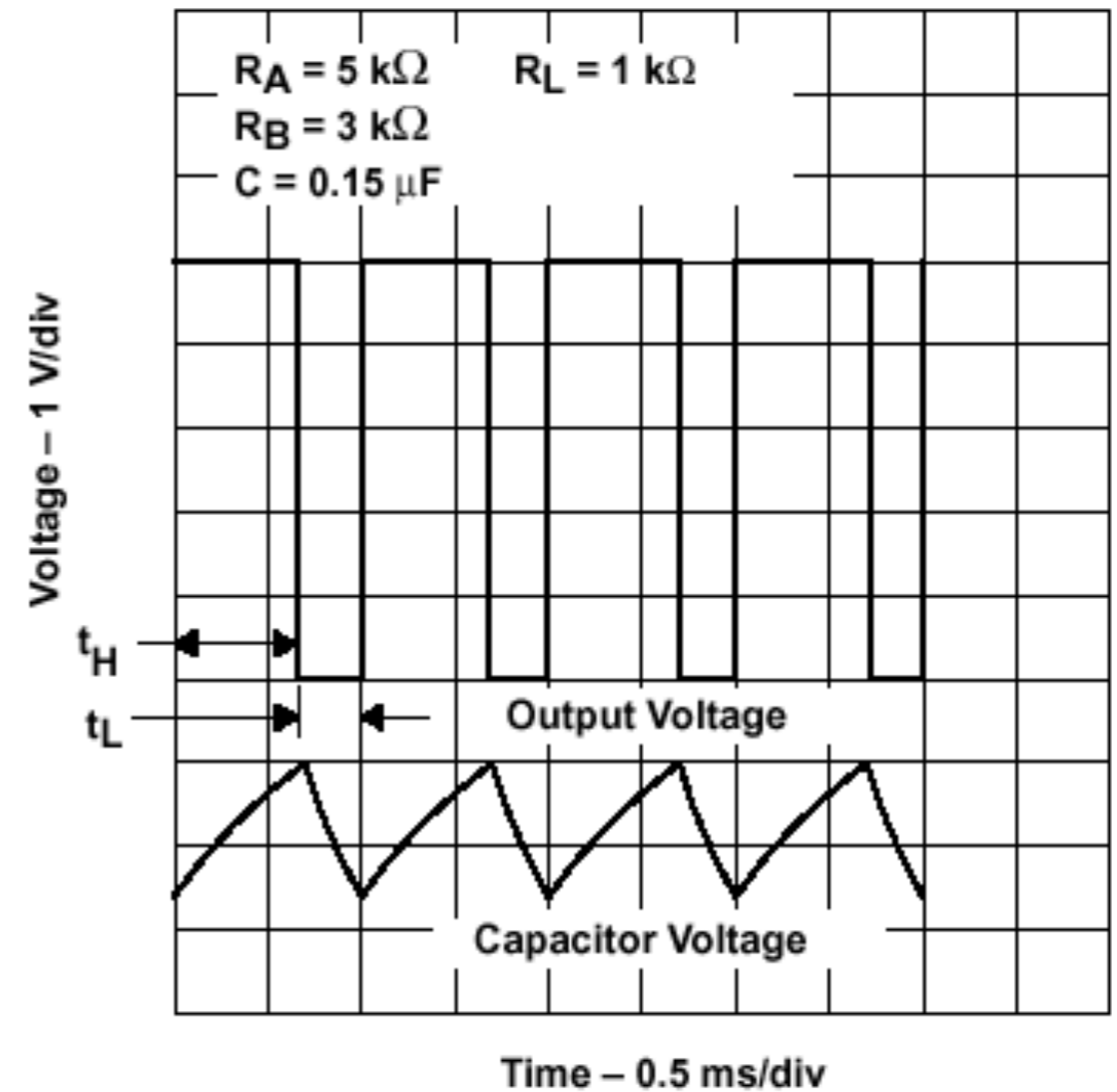
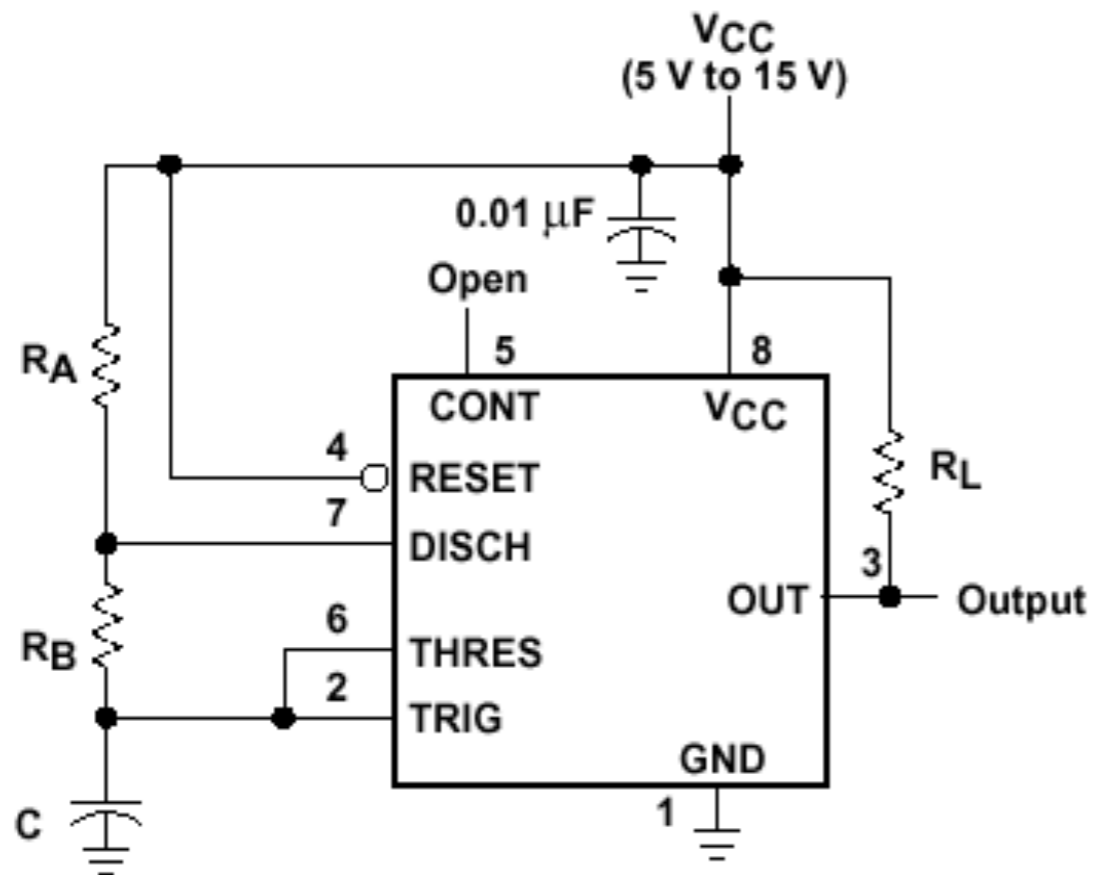
$$V_6 > \frac{2}{3} V_{cc}$$

$$V_2 < \frac{1}{3} V_{cc}$$



Circuitos Analógicos

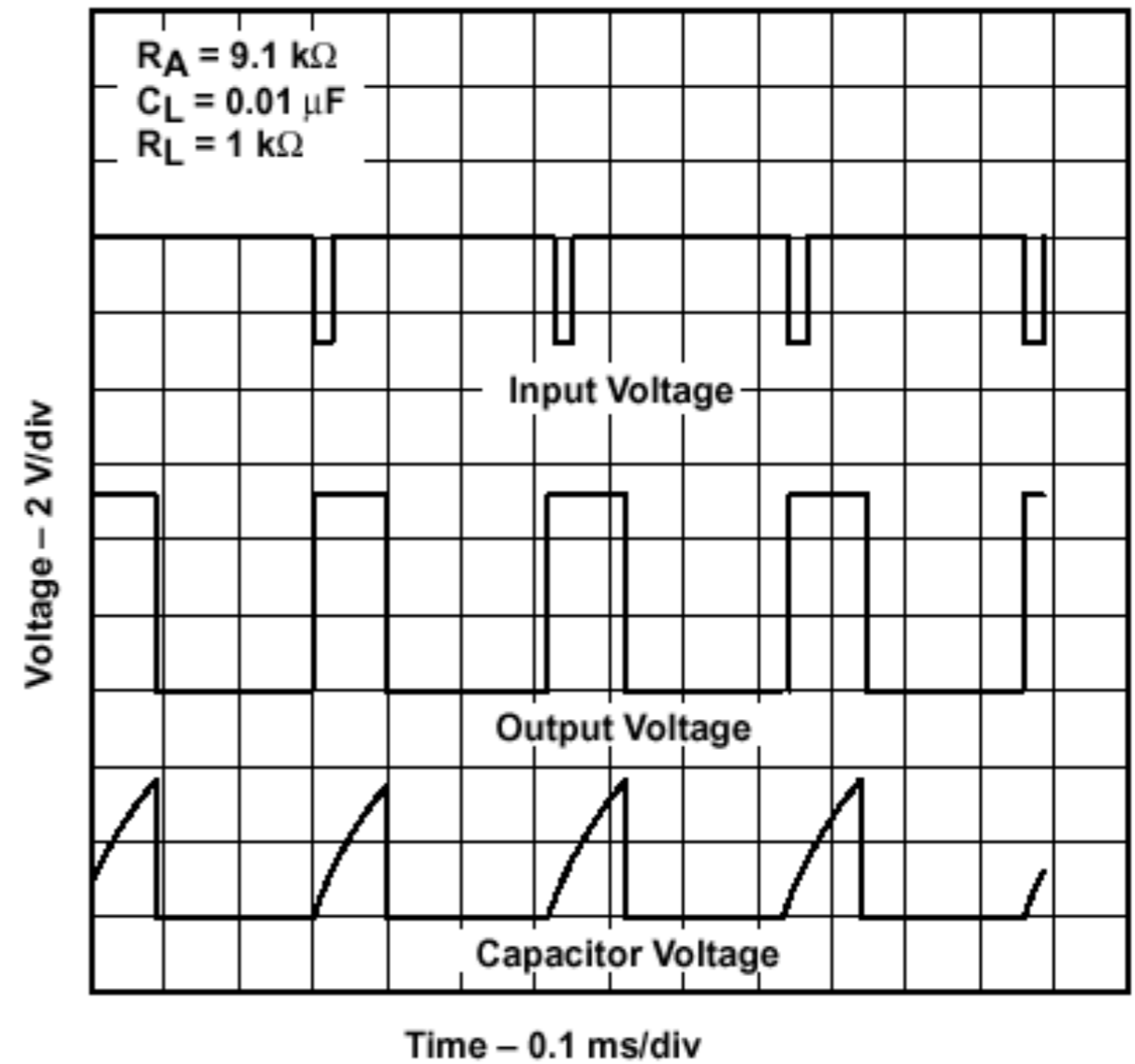
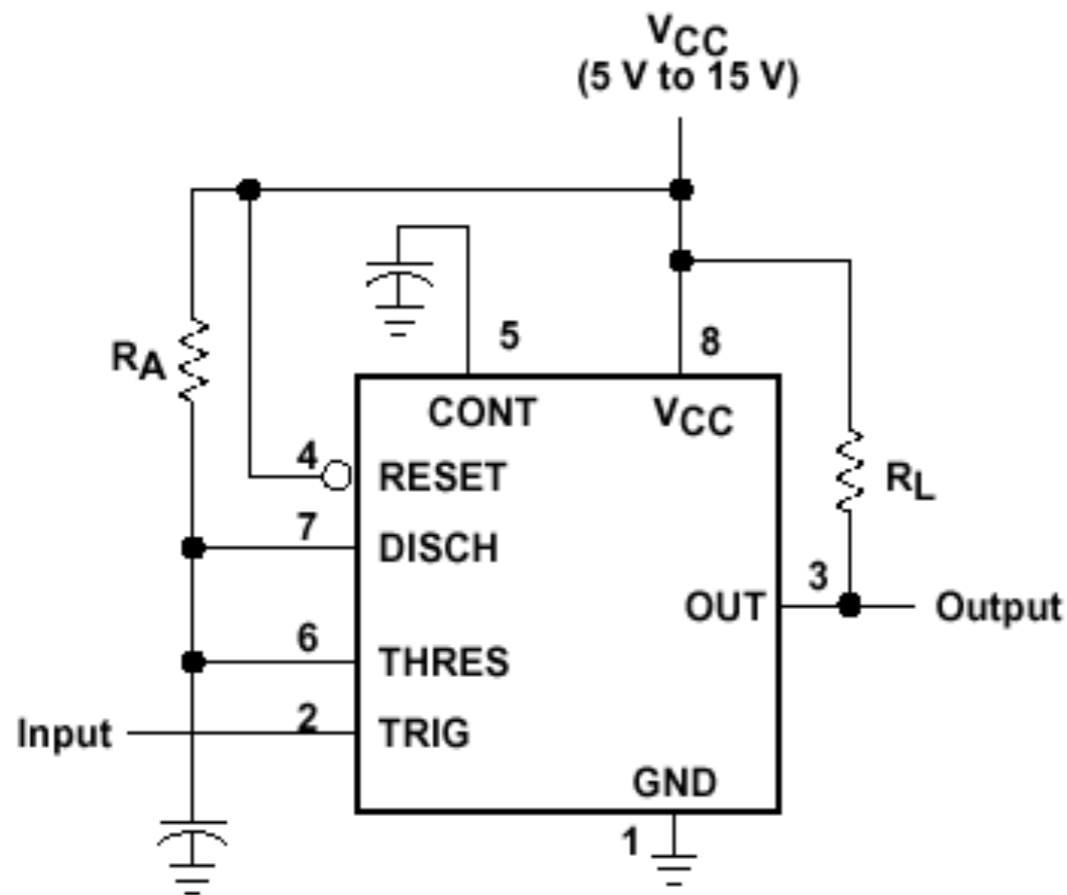
Modulador PWM usando temporizador 555:



Multivibrador astável

Circuitos Analógicos

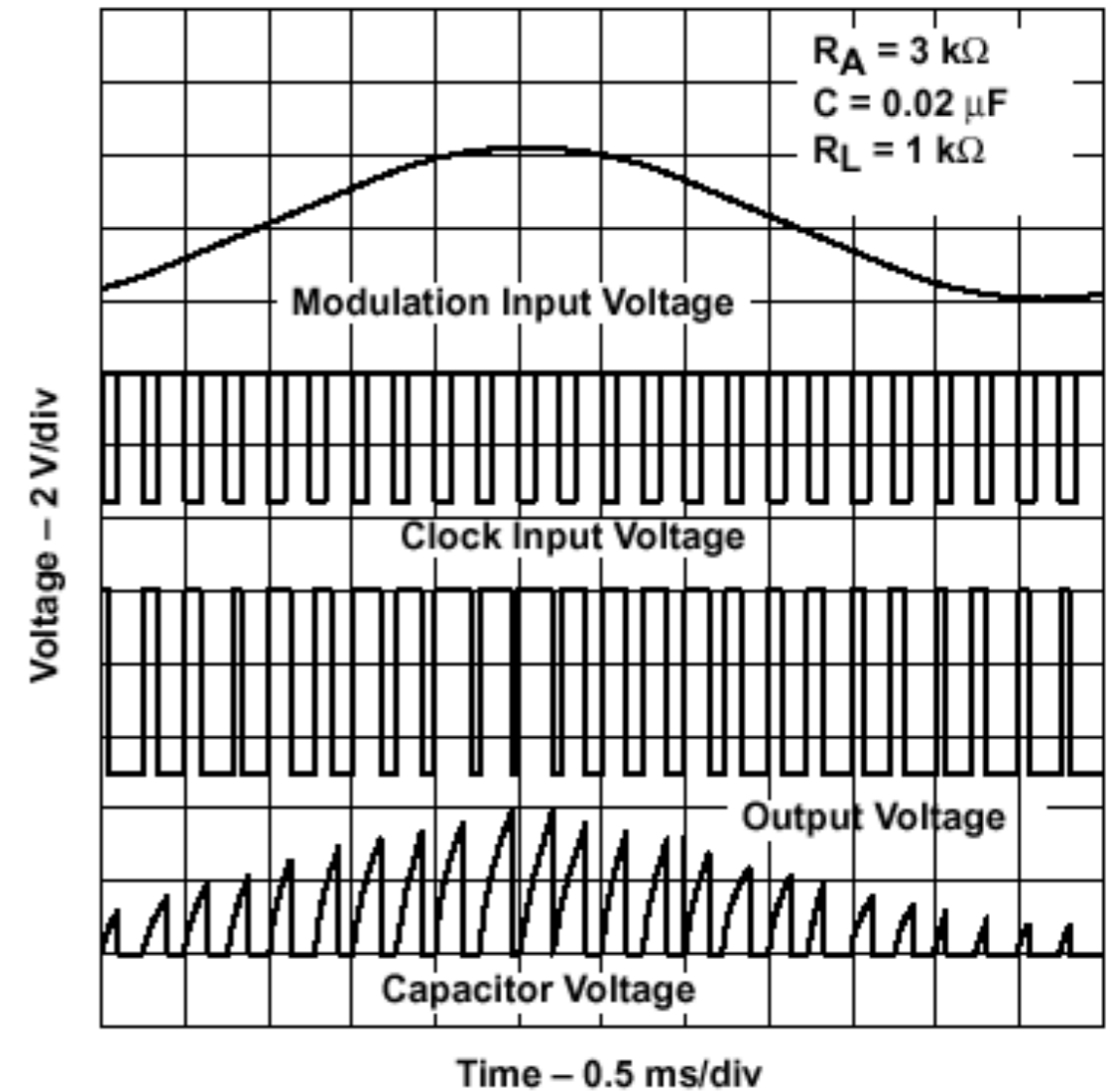
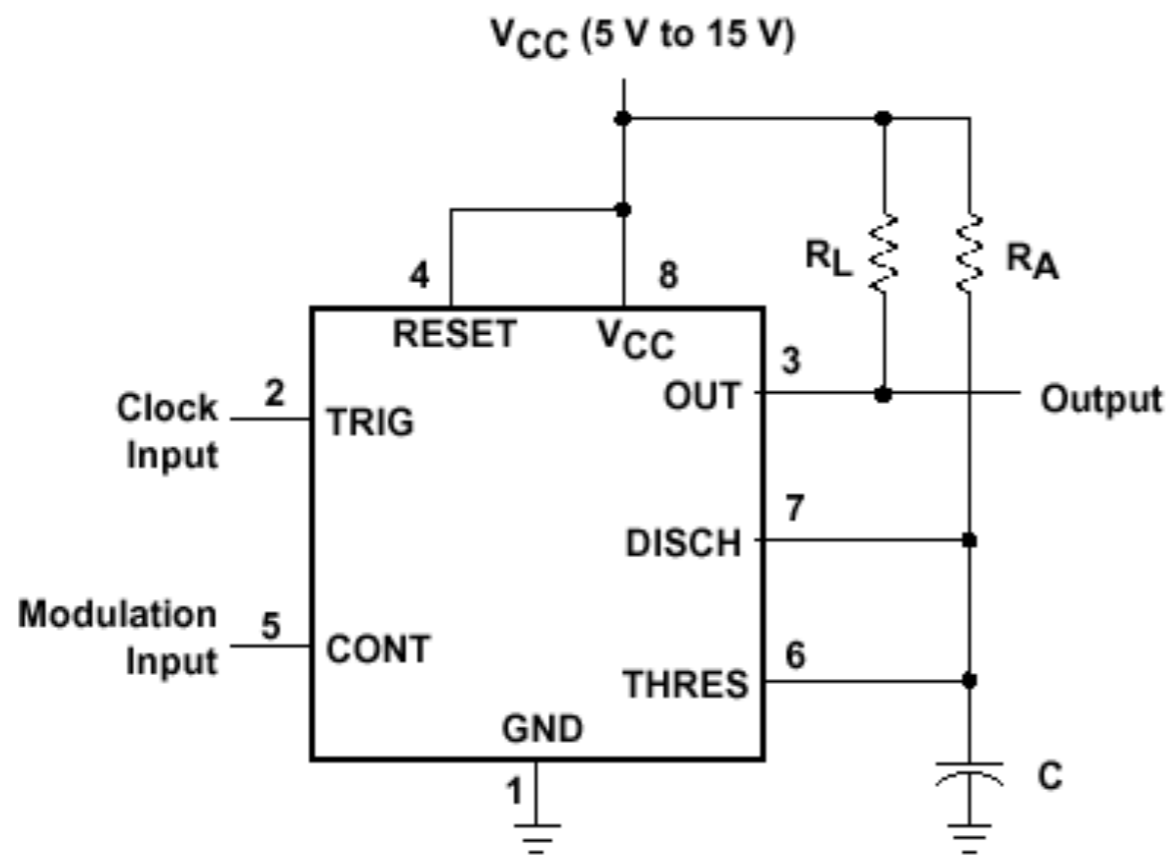
Modulador PWM usando temporizador 555:



Multivibrador monoestável

Circuitos Analógicos

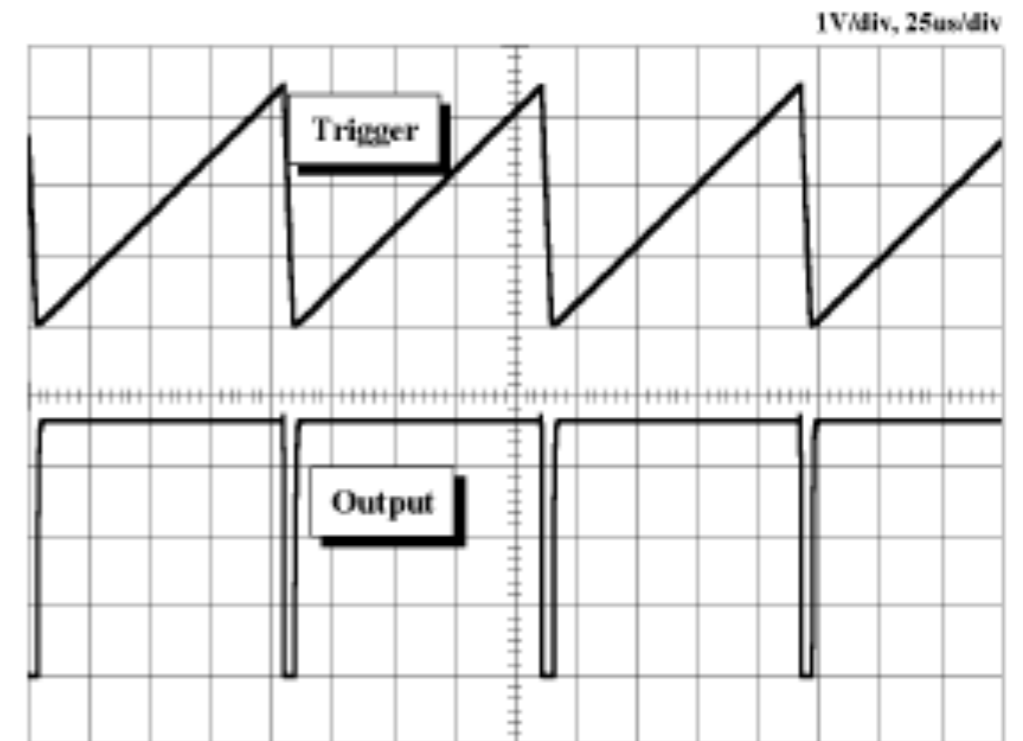
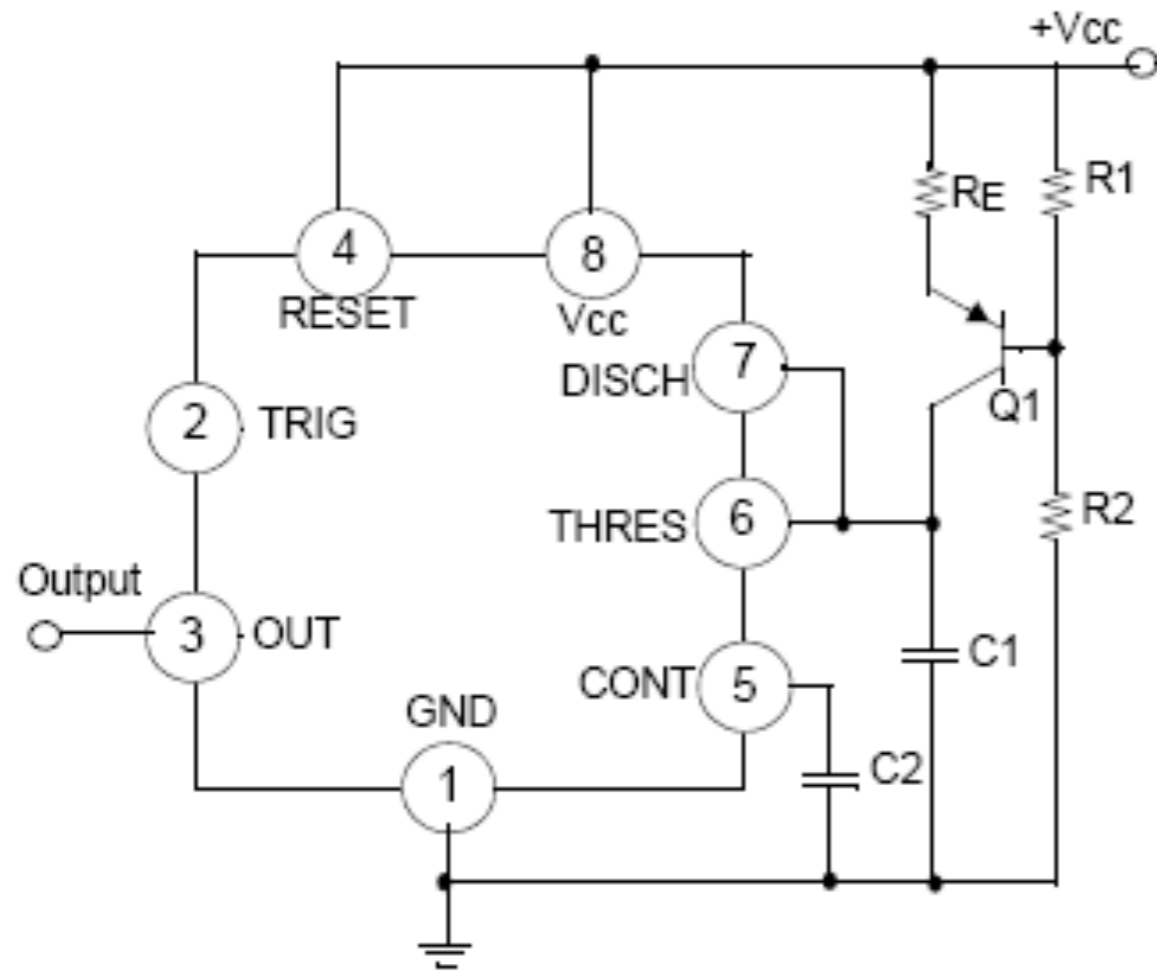
Modulador PWM usando temporizador 555:



Modulador PWM

Circuitos Analógicos

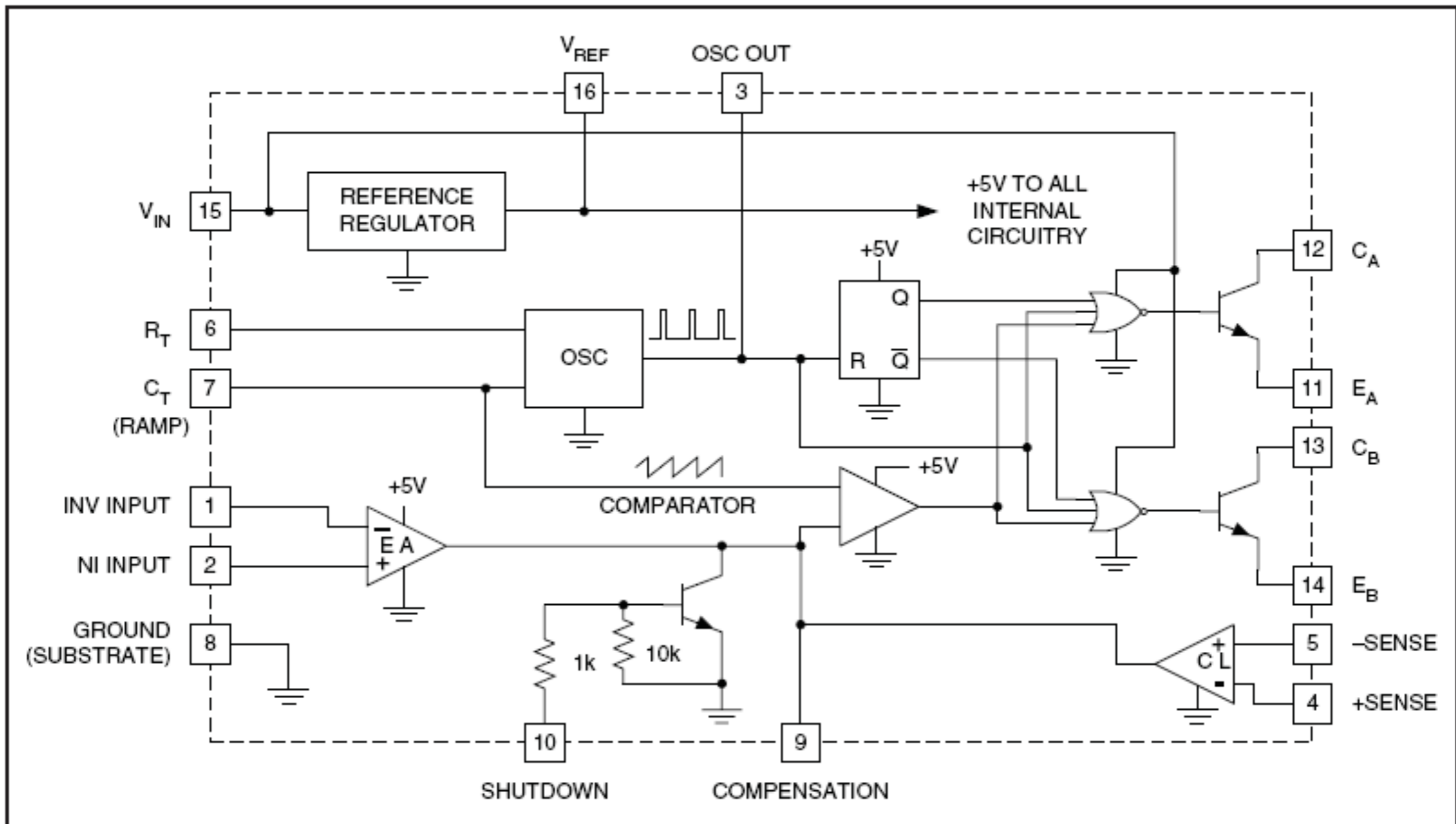
Gerador de rampa usando o temporizador 555:

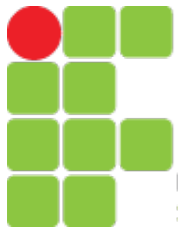


$R1=47k\Omega$, $R2=100k\Omega$, $R_E=2.7k\Omega$, $R_L=1k\Omega$, $C1=0.01\mu F$, $V_{cc}=5V$

Circuitos Dedicados

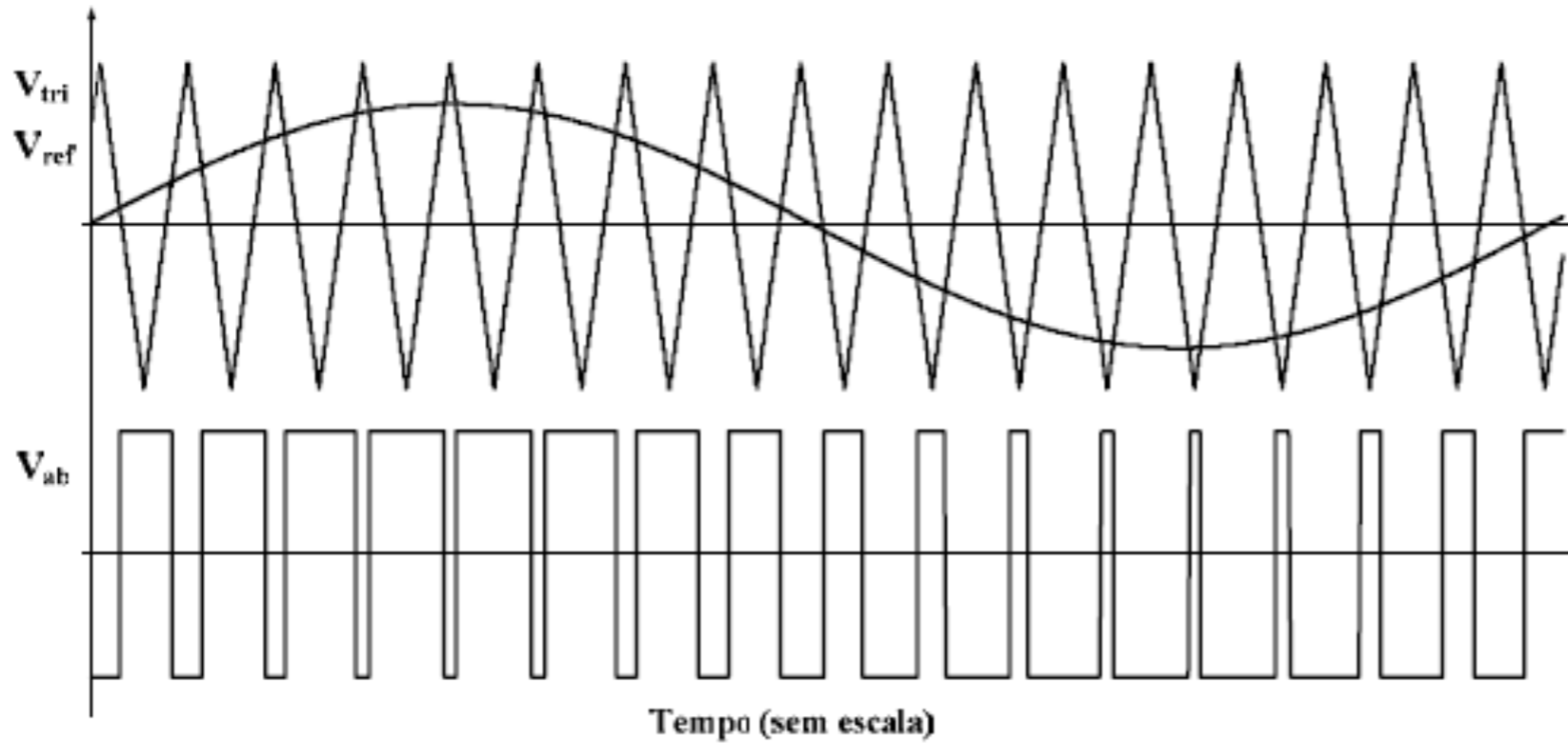
UC3524N:



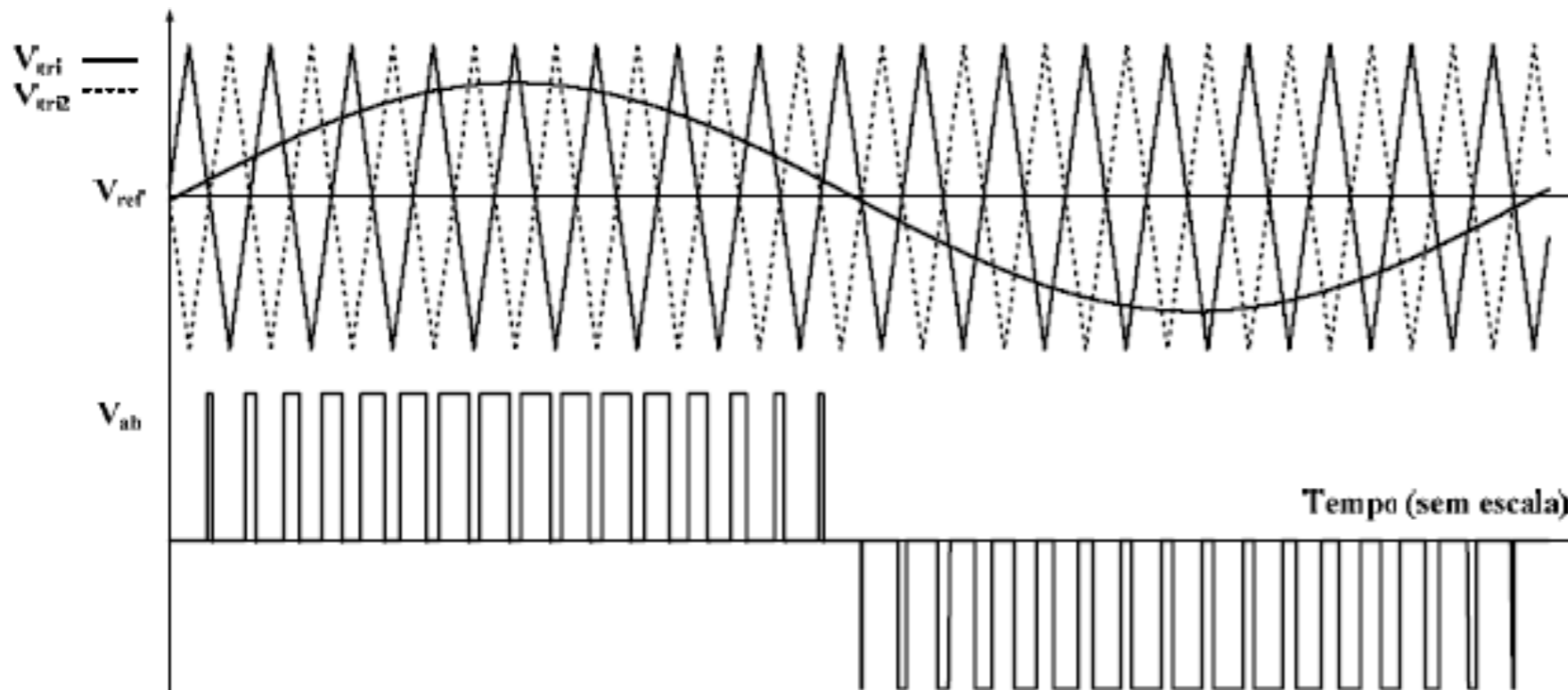


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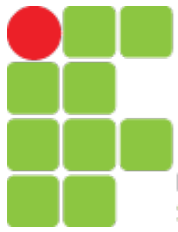
Circuitos Dedicados



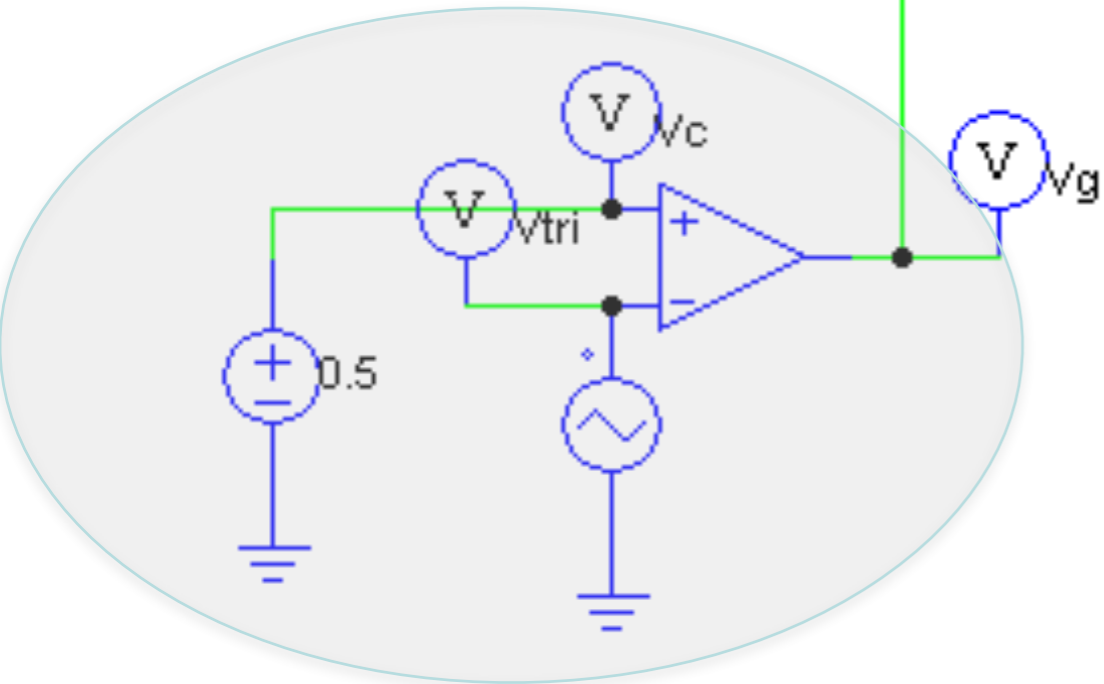
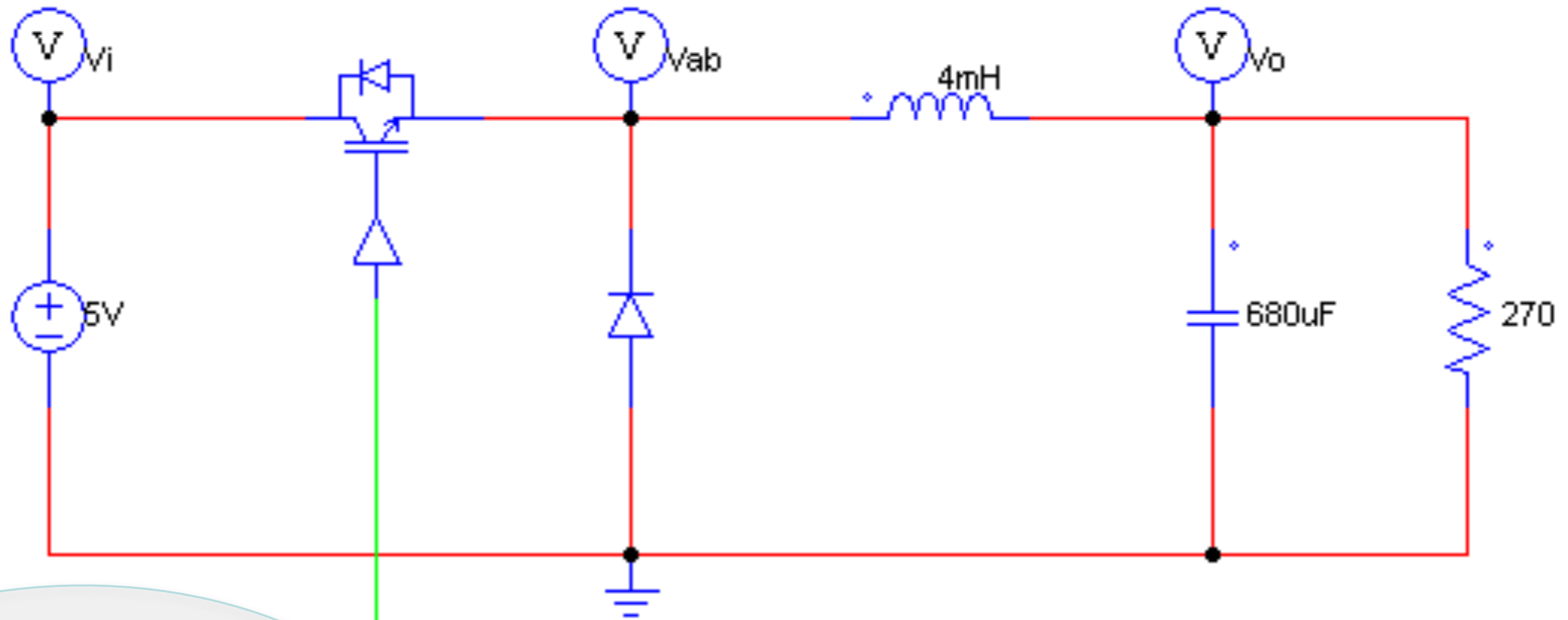
Dois níveis



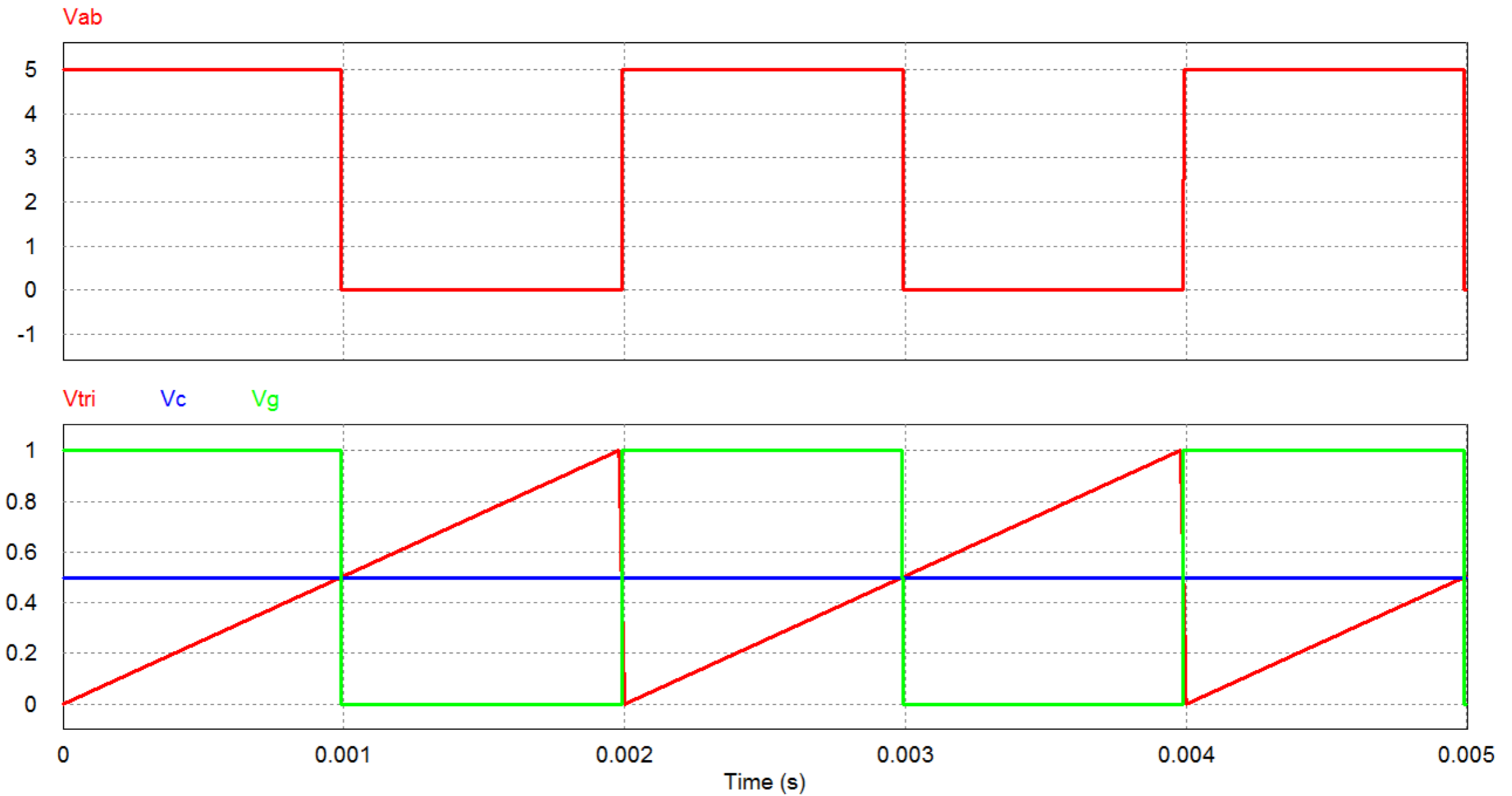
Três níveis

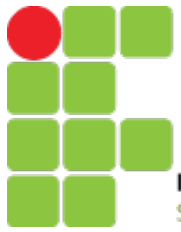


Simulação de Conversor CC-CC



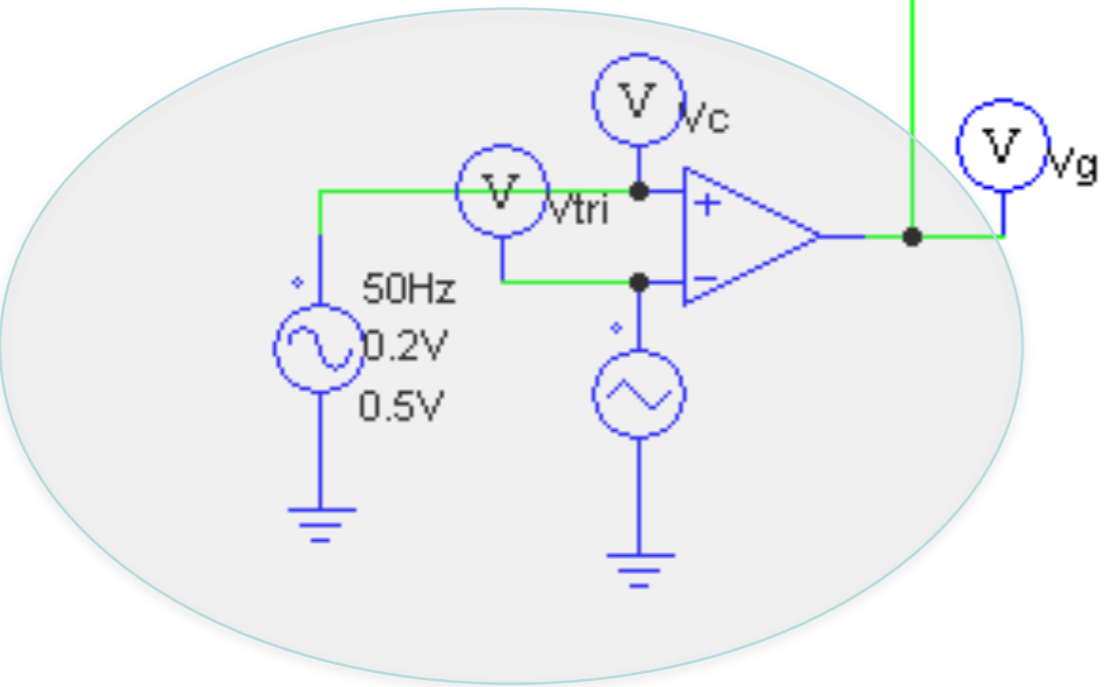
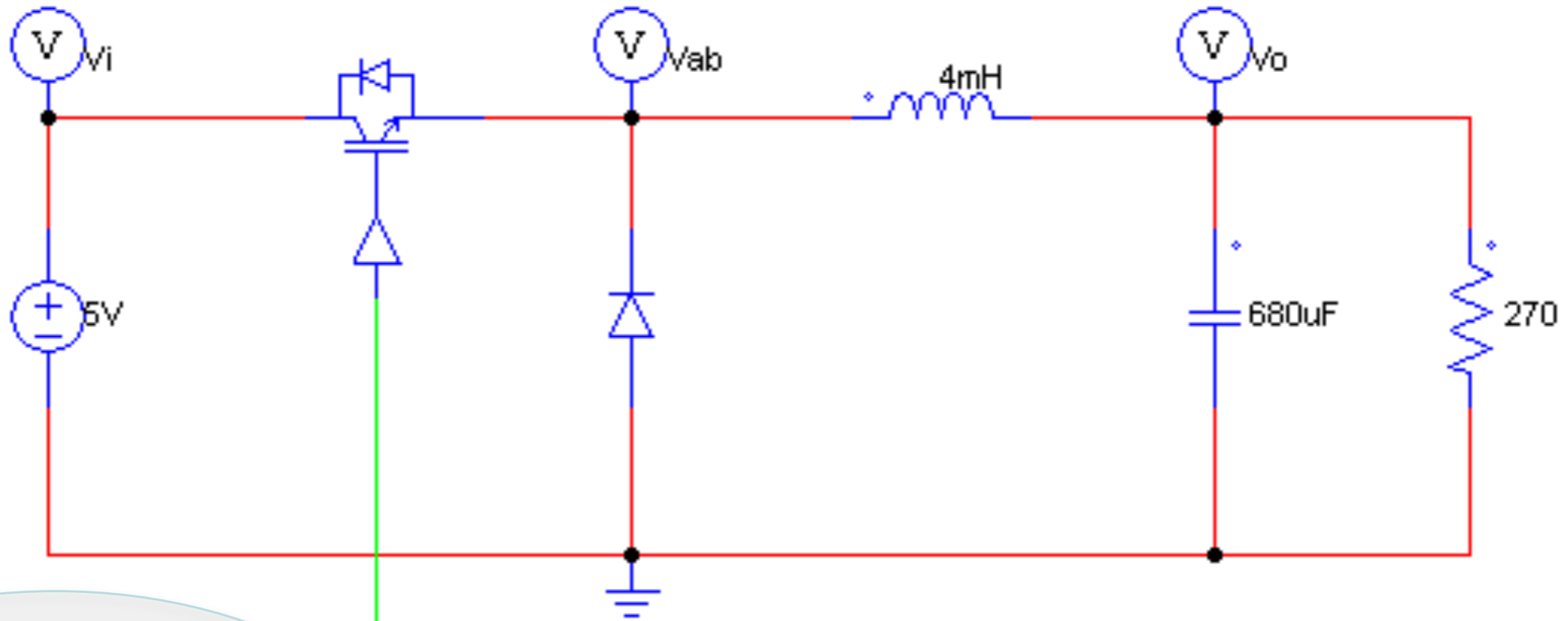
Simulação de Conversor CC-CC



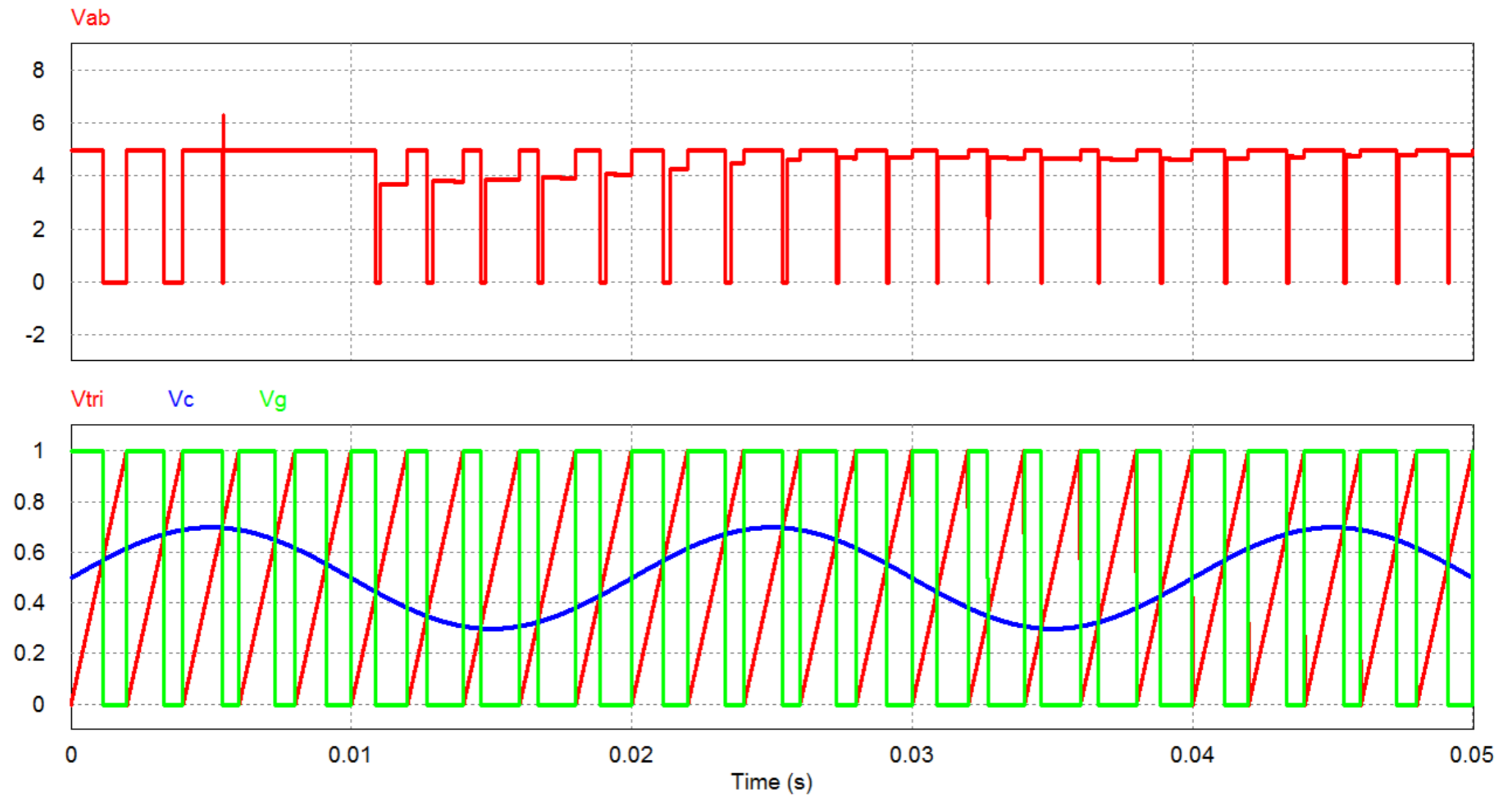


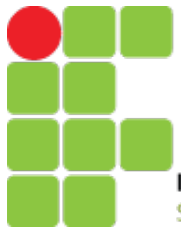
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Simulação de Conversor CC-CA

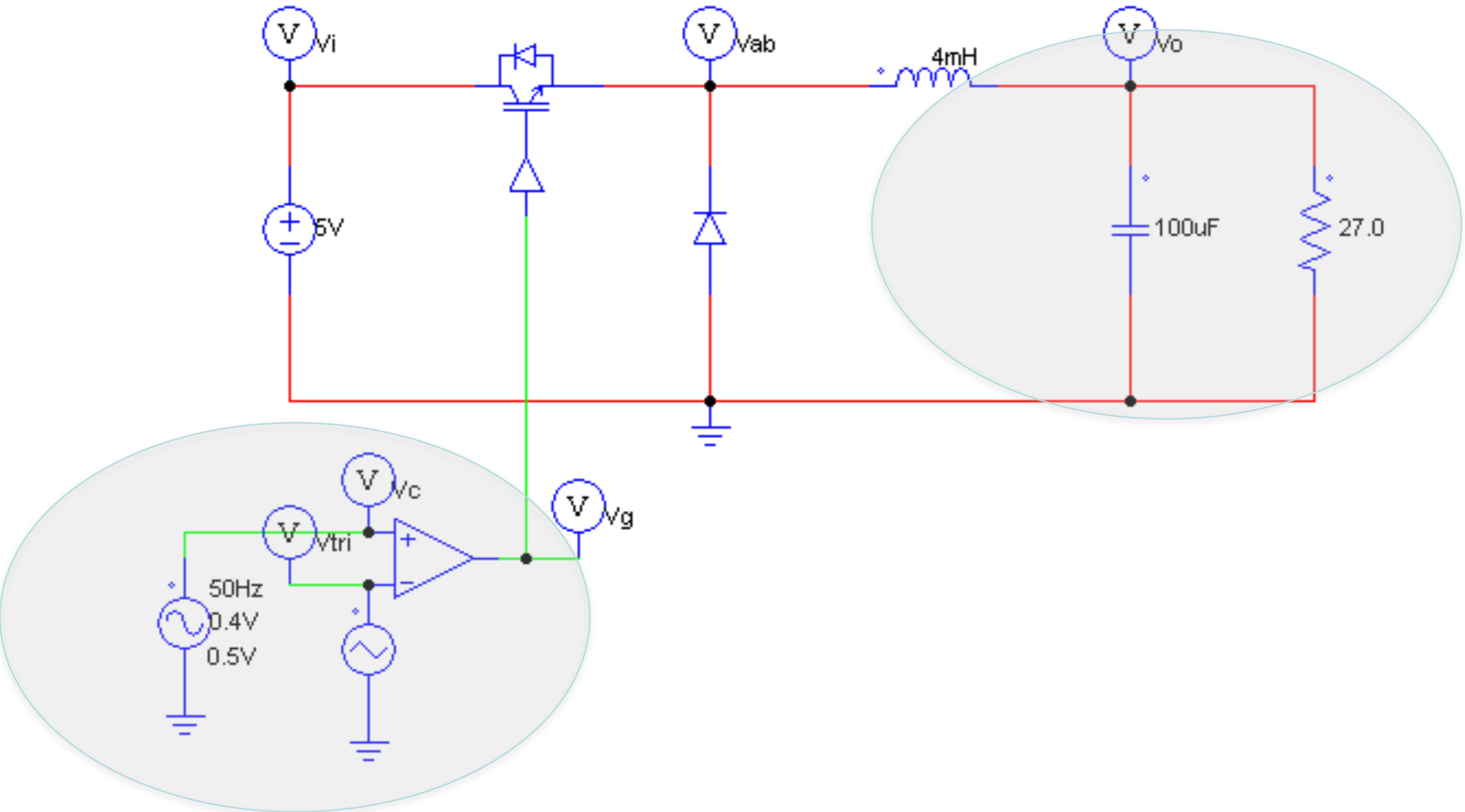


Simulação de Conversor CC-CA

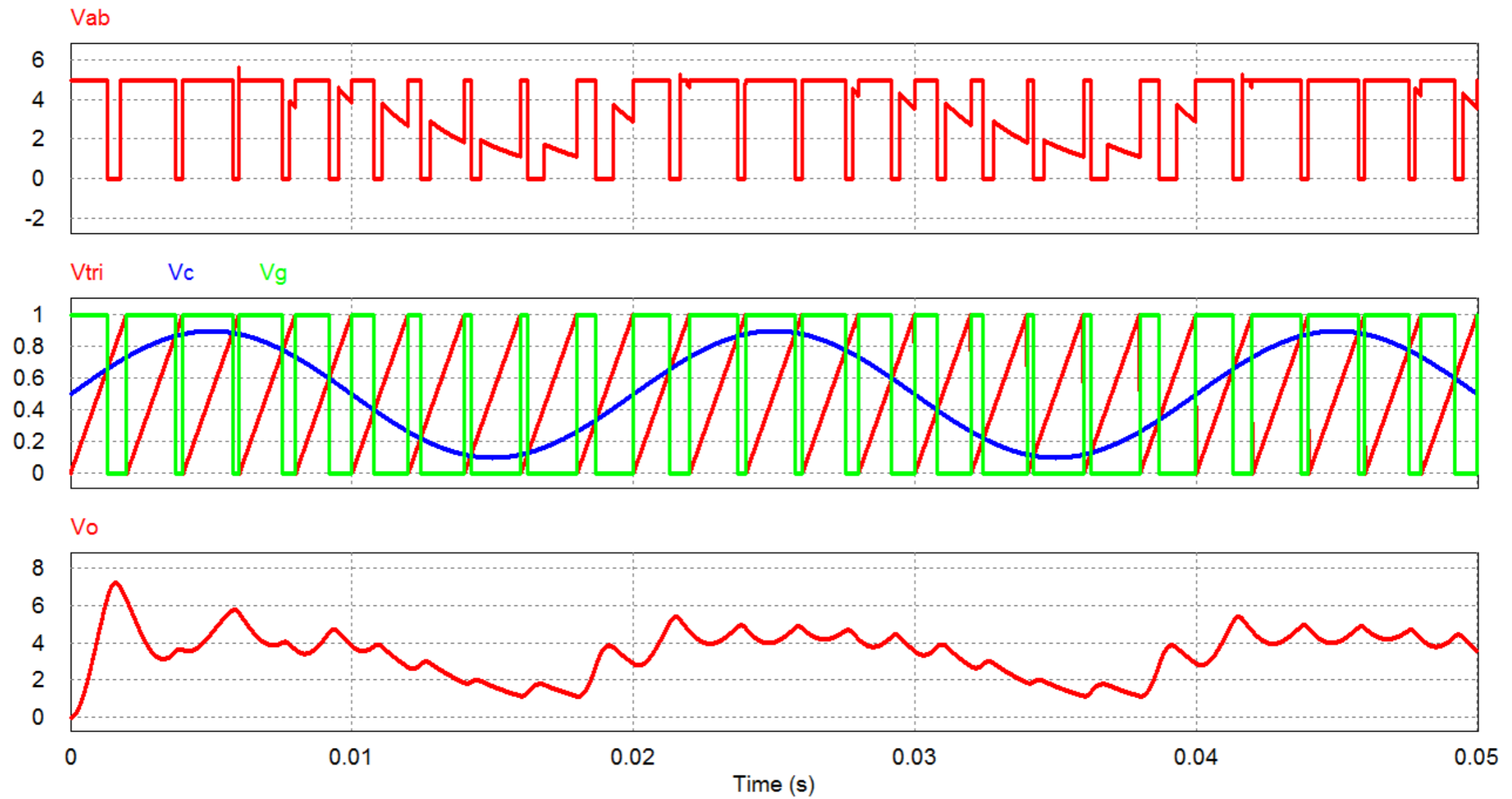




Simulação de Conversor CC-CA



Simulação de Conversor CC-CA



Próxima Aula

Conversores cc-ca:

- Conversor meia ponte.

